

BASIS AND BACKGROUND INHALATION PATHWAY

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Basis and Background

Inhalation Soil Remediation Standards

I. Introduction

The Department has been directed by the Legislature to develop human health based soil remediation standards for residential and nonresidential exposure scenarios, N.J.S.A. 58:10-1 et seq. To prevent the unacceptable risk to human health from inhalation of contaminated particulates or vapors emanating from contaminated soil, the Department has developed soil remediation standards for the inhalation exposure pathway. The Department considered human health effects for both carcinogenic and noncarcinogenic contaminants. The Legislature determined that standards would be set at one additional cancer risk in one million (1×10^{-6}) for carcinogens and a hazard quotient not to exceed one for noncarcinogens.

Specifically, this document will explain and describe the approach developed by the Department to assess the inhalation exposure pathway. The inhalation pathway is a primary route of human exposure to contamination and is found at residential and nonresidential sites. Generally accepted methods, models, and assumptions have already been developed to evaluate this pathway. This includes a large volume of material gathered by the USEPA. The USEPA documents entitled Soil Screening Guidance: Technical Background Document (USEPA, 1996a), and Supplemental Guidance for Developing Soil Screening levels for Superfund Sites (USEPA, 2001) serve as the basis for the Department's development of soil cleanup standards for the inhalation pathway. These USEPA guidance documents will be collectively referred to hereafter as the soil screening guidance documents (SSG).

The generic Soil Remediation Standards for the Inhalation Pathway are to be used at any site. However, the Department recognizes that the inclusion of site-specific conditions may be appropriate in determining alternative remediation standards. If the soil contamination levels at the site are below the Inhalation Soil Remediation Standards (InhSRS), then no further action is required relative to this exposure pathway. When contaminant levels exceed the InhSRS, one

could remediate the contamination levels below the appropriate standard(s) and no further action would be required relative to this exposure pathway.

Site-specific characteristics may be substituted for default inputs in the algorithm in order to calculate alternative remediation standards for the site. The site-specific factors that may be substituted are discussed further within Section VI of this Basis and Background document and are subject to Department approval. A third approach could be taken to evaluate the contamination levels at a site. This approach would involve using alternative models and assumptions. Such an approach is not discussed in Section VI but may be permissible with Department oversight and acceptance.

The remainder of this basis and background document is divided into a discussion of the development of generic InhSRS for contamination in both volatile and particulate form. Within each section, the equations and assumptions used in developing the generic standards are explained. Exposure in residential and nonresidential settings using carcinogenic and noncarcinogenic endpoints is assessed. Subsequent sections present the methods and information that are needed to develop alternative remediation standards. Finally, sensitivity analyses for volatile and particulate contaminants were conducted and are presented.

II. Methodology for Developing Generic Standards

A. Overview

USEPA toxicity data indicate that the risks from exposure to some contaminants in the soil via the inhalation pathway are greater than the risks via other pathways, such as direct ingestion. Therefore, InhSRS were developed by the Department to be protective of the air exposure pathway.

The central principle employed in developing the generic standards was to establish viable methodologies for calculating values and to apply these to the full range of exposure scenarios and contaminants that need to be assessed. Having established a potential universe of proposed standards, the products of these efforts were evaluated with the goal of selecting the process that was the most technically sound and defensible.

The inhalation exposure pathway has two components that were used to develop soil remediation standards, the volatile organic compounds and the particulate compounds.

USEPA's Soil Screening Guidance: Technical Background Document explains that the volatile organic compounds and the particulate compounds were dealt with separately because the "Inhalation risk from fugitive dusts results from particle entrainment from the soil surface; thus contaminant concentrations in the surface soil horizon (e.g., the top 2 centimeters) are of primary concern for this pathway under the current scenario. While the entire column of contaminated soil can contribute to volatile emissions at a site, the top 2 centimeters are likely to be depleted of volatile contaminants at most sites. Thus, contaminant concentrations in subsurface soil, which are measured using core samples, are of primary concern for quantifying the risk from volatile emissions" (USEPA 1996a, page 21). It should be noted that subsurface soil may be brought to the surface in a future scenario and may then present an unacceptable inhalation risk from volatile organic compounds and particulates. Because of this, the Department has elected to evaluate particulate contamination at the surface via a 2-foot deep interval without a separate evaluation of the 0 to -2 centimeter layer.

In the SSG, soil screening levels (SSL) are developed to address the residential exposure scenario for volatile organic compounds and particulates using updated versions of the models, assumptions, and risk assessment methods originally presented in the USEPA document entitled Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual - Part B (USEPA, 1991c). Of particular note with regard to updates is the use of the Jury, Farmer, and Spencer (1984) model to replace the model originally used to calculate the volatilization factor for volatile organic compound SSL. As indicated before, the SSG documents were selected as the best starting point for the development of the overall methodology.

For the nonresidential exposure scenario where volatile organic compounds are involved, the guidance provided in the USEPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2001) will be employed. Consultation with the USEPA indicated that a modification of SSG's short-term construction scenario, which includes a vehicular component, was not recommended to address the inhalation of particulates. Consequently, an alternative course of action was necessary. Clearly, the USEPA thought the inclusion of vehicle traffic was appropriate for a short-term construction scenario. Such a scenario represents an extreme worst case relative to the potential for the generation of dust. Examination of the residential and nonresidential exposure scenarios led the Department to conclude that vehicular traffic and in particular truck traffic was also typical of the general nonresidential exposure scenario and a major distinction between these two exposure scenarios. Evaluation of the magnitude of the impact of truck traffic indicated that it would exceed a solely wind generated component by a wide margin. The Department's concern about dust generated by more typical vehicle activity is merely an extension of the USEPA's logic in the short term construction scenario. However, the question of why the USEPA does not consider vehicle activity under its other nonresidential exposure scenarios and the Department does is based more on the requirement for the Department to evaluate future use situations without consideration of institutional or engineering controls.

While the Department tries to be consistent with the USEPA, differences in their respective approaches exist. The USEPA tends to focus on current use or known future use in assessing what is an appropriate expectation. The Department takes a more conservative approach,

particularly in dealing with sites where a potential unconditional no further action determination is being considered. Future use is assessed by evaluating the site excluding all institutional and engineering controls. This is done even if such features or their equivalents are currently present. If a site subject to heavy truck traffic is evaluated assuming an absence of paving, the concern about fugitive dust emissions would necessarily be greatly magnified. On the other hand, if paving is assumed to be present at the same facility, the concern is reduced to an insignificant level. This probably accounts for why the USEPA is concerned about vehicle traffic under a short term construction scenario, but not under a standard nonresidential exposure scenario in contrast to the Department.

USEPA models were investigated as a way to develop particulate related standards for these nonresidential exposure scenarios. This process led to the conclusion that pairing the AP-42 emission factors (Compilation of Air Pollutant Emission factors, Volume I: Stationary Point and Area Sources USEPA, 1998a) and the Industrial Source Complex Short Term Version 3 (ISCST3) (USEPA, 2002) model was the best choice to address this situation. AP-42 estimates emissions while the ISCST3 assesses the dispersion of these emissions, making it possible to assess the impact of vehicular traffic. AP-42 in combination with another dispersion model, the Fugitive Dust Model (FDM) (USEPA, 1992a), has a similar capability. AP-42 and ISCST3 were selected by the Department to use as the default because first, these are the methods of choice for the USEPA. Secondly, the calculation of alternative site-specific values can be more readily done using this combination. Finally, the output from the AP-42 and ISCST3 pairing is more protective than the output from AP-42 and the FDM model.

The net result was that for the residential exposure scenario, the standards for the particulate compounds were calculated using the SSG methodology. The particulate compounds under a nonresidential exposure scenario would employ AP-42 and the ISCST3 model to derive a standard. Nonvolatile and semi-volatile organic compounds were evaluated as inhalable particulates emitted by wind erosion and by mechanical resuspension by vehicle traffic to evaluate whether or not the adherence of these compounds to dust particles represented a significant hazard.

B. Toxicity Factors for Inhalation Pathway

All of the toxicity data used to develop InhSRS for volatile, semivolatile, and particulate contamination can be found in Appendix A. The unit risk factors (URFs) for carcinogens and reference concentrations (RfCs) for noncarcinogens that are used for the evaluation of inhalation toxicity were taken from a number of sources, which are described below. Each chemical-specific reference is given in Appendix A. The following describes the hierarchy used specifically for the inhalation pathway. It is consistent with the hierarchies established for the other pathways, taking into account the preference for inhalation-based data.

Class C carcinogens are those classified by USEPA as "possible human carcinogens." There is limited evidence of their carcinogenicity in animals, and inadequate human data. For the development of soil remediation standards, the Department has developed a policy for Class C carcinogens with RfCs (for noncarcinogenic effects). To add an additional safety factor to the toxicity data for these possible carcinogens, the RfC is divided by ten. This policy and its standardized application for all pathways are discussed in the Interested Party Review introduction. Listed in Appendix B are the compounds that are impacted by the Class C carcinogen policy.

The Department has determined a hierarchy for obtaining toxicity information that is generally applied to all exposure pathways for the development of soil remediation standards. USEPA's on-line Integrated Risk Information System (IRIS) (USEPA, 2003a) is the first choice under the Department's hierarchy for current inhalation toxicity data. It is the source of 33 URFs and 28 RfCs.

The next preferred source of inhalation toxicity data preferred for inhalation pathway use is the California Environmental Protection Agency, which is an umbrella agency which includes the Office of Environmental Health Hazard Assessment and the California Air Resources Board. Twenty-eight URFs and 22 RfCs came from this source.

Another major source of toxicity data is the USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997a) which were last revised in 1997. This source is used when

data are not available from the above two sources. HEAST was referred to for 4 URFs and 13 RfCs.

Other sources of toxicity data include Toxicology Excellence for Risk Assessment (TERA)(TERA, 1999), the Agency for Toxic Substances and Disease Registry (ATSDR)(ATSDR, 2003), and a paper by I.C.T. Nisbet and P.K. LaGoy on toxic equivalency factors for polycyclic aromatic hydrocarbons (Nisbet and LaGoy, 1992).

A RfC for lead was developed by the Department's Bureau of Air Quality Evaluation (BAQEv) using USEPA's LEAD5 Model, Version 5 (NJDEP/BAQEv, 2003).

For antimony (total), an IRIS RfC for antimony trioxide was used. The arsenic URF is based on an IRIS URF for inorganic arsenic. For chlordane, an IRIS RfC for technical grade chlordane was used.

For a number of contaminants, there were no inhalation toxicity data to be found. If oral toxicity data were available, they were converted to inhalation units. Most of these converted oral data came from IRIS and HEAST, some from the Department's drinking water quality standards (A280)(NJDWQI, 1987; NJDWQI, 1994), and a few from the National Center for Environmental Assessment (NCEA), part of USEPA's Superfund Technical Support Center in Cincinnati, Ohio (USEPA, 2003b).

Using the sources listed above, neither inhalation nor oral data could be found for 4-chloro-3-methyl phenol, dibenzofuran, dimethyl phthalate, and 4-nitrophenol. Therefore, no generic standards were developed for these contaminants.

III. The Development of Generic Inhalation Standards for Volatiles

A. Calculations

The equations for the InhSRS of carcinogenic and noncarcinogenic volatile contaminants in soil are given below. The target cancer risk of 1×10^{-6} and the target hazard quotient of one are used by USEPA and are also mandated by the Brownfield Contaminated Site Remediation Act (N.J.S.A. 58:10-1 et seq.). The Department uses the USEPA SSG methodology for volatile organic contaminants for both residential and nonresidential exposure.

Equations for Calculating Inhalation Soil Remediation Standards for Volatile Organics:

Carcinogens

$$\text{Inh}_v\text{SRS}_c = \frac{TR \times AT \times 365 \frac{\text{days}}{\text{year}}}{URF \times 1000 \frac{\mu\text{g}}{\text{mg}} \times EF \times ED \times \left(\frac{1}{VF}\right)} \quad \text{Equation 1}$$

Noncarcinogens

$$\text{Inh}_v\text{SRS}_n = \frac{THQ \times AT \times 365 \frac{\text{days}}{\text{year}}}{EF \times ED \times \left(\frac{1}{RfC}\right) \times \left(\frac{1}{VF}\right)} \quad \text{Equation 2}$$

Inh_vSRS_c = Inhalation soil remediation standard for volatile carcinogens (mg/kg)

Inh_vSRS_n = Inhalation soil remediation standard for volatile noncarcinogens (mg/kg)

TR = Target cancer risk (unitless)

THQ = Target hazard quotient (unitless)

AT = Averaging time (years)

URF = Inhalation unit risk factor ($\mu\text{g}/\text{m}^3$)⁻¹

RfC = Inhalation reference concentration (mg/m^3)

EF = Exposure frequency (day/year)

- ED** = Exposure duration (years)
VF = Soil-to-air volatilization factor (m³/kg)

Equation for Calculating Volatilization Factor (VF):

$$VF = Q / C_{vol} \times \frac{(3.14 \times D_A \times T)^{1/2}}{2 \times \rho_b \times D_A} \times 10^{-4} \frac{m^2}{cm^2}$$

Equation 3

- VF** = Soil-to-air volatilization factor (m³/kg)
Q/C_{vol} = Inverse concentration at center of source (g/m²-s per kg/m³)
(specific to volume)
D_A = Apparent diffusivity (cm²/s)
T = Exposure interval (seconds)
ρ_b = Dry soil bulk density (g/cm³)

Equation for Calculating Apparent Diffusivity (D_A):

$$D_A = \frac{[(\theta_a^{10\%} \times D_i \times H') + (\theta_w^{10\%} \times D_w)] / n^2}{(\rho_b \times K_d) + \theta_w + (\theta_a \times H')}$$

Equation 4

- D_A** = Apparent diffusivity (cm²/s)
θ_a = Air-filled soil porosity (L air/L soil)
D_i = Diffusivity in air (cm²/s)
H' = Henry's Law Constant (unitless)
θ_w = Water-filled soil porosity (L water/L soil)
D_w = Diffusivity in water (cm²/s)
n = Total soil porosity (L pore/L soil)
ρ_b = Dry soil bulk density (g/cm³)
K_d = Soil-water partition coefficient (cm³/g)

Equation for Calculating Soil-Water Partition Coefficient (K_d):

$$K_d = K_{oc} \times f_{oc} \quad \text{Equation 5}$$

K_d = Soil-water partition coefficient (cm^3/g)

K_{oc} = Soil organic carbon-water partition coefficient (cm^3/g)

f_{oc} = Organic carbon content of soil (g/g)

Equation for Calculating Air-Filled Soil Porosity (θ_a):

$$\theta_a = n - \theta_w \quad \text{Equation 6}$$

θ_a = Air-filled soil porosity (L air/L soil)

θ_w = Water-filled soil porosity (L water/L soil)

n = Total soil porosity (L pore/L soil)

B. Default Input Parameters

The methodology for calculating InhSRS for volatile contaminants is taken from USEPA's Soil Screening Guidance: Technical Background Document (USEPA 1996a,). The input parameters used by the Department were the same as those used by USEPA (1996a, 2001), except for air dispersion and certain soil characteristics. These exceptions are noted in Tables 1 and 2, below. For the volatile pathway, the difference between the residential and nonresidential scenarios is exposure time, including averaging time (AT), exposure frequency (EF), exposure duration (ED), and exposure interval (T).

A sensitivity analysis of the inhalation model for volatile contaminants is presented in Appendix C. Some of these analyses are discussed further below.

The Q/C value gives an estimate of dispersion based on meteorological conditions. It was changed from USEPA's default value based on meteorological modeling for New Jersey.

Soil texture may significantly affect the soil moisture content, which in turn has a substantial effect on the volatilization rate of volatile organic chemicals. Heavier soils such as loam soils, or those with significant clay content tend to have higher moisture contents that can significantly reduce volatilization. The USEPA uses loam as its default soil texture, based on nationwide data. However, because the southern half of New Jersey is primarily composed of sandy loam and sand soils (Tedrow, 1986), it was determined that a loam soil texture would not be protective of many areas of the state. A sandy loam soil was selected as the generic soil texture, which is more representative of hydrologic conditions in southern New Jersey than loam soil. Sand was not used as the default soil texture because sand is too porous to be representative of northern New Jersey; and sand is primarily located in the Pine Barrens of New Jersey and in coastal areas, where fewer contaminated sites are located.

The USEPA default characteristics were altered slightly to generate default values for New Jersey. These values are representative of a sandy loam soil: total soil porosity (n); water-filled soil porosity (θ_w); air-filled soil porosity (θ_a); and organic carbon content of soil (f_{oc}).

Comparison of USEPA's and the Department's default parameters are given in Table 1 below.

Table 1 Comparison of Input Parameters			
Parameters		NJDEP Default	USEPA Default
θ_w	water-filled soil porosity	0.23 L water/L soil	0.15 L water/L soil
n	total soil porosity	0.41 L pore/L soil	0.43 L pore/L soil
θ_a	air-filled soil porosity	0.18 L air/L soil	0.28 L air/L soil
f_{oc}	organic carbon content of soil	0.002 g/g	0.006 g/g surface

AIR-FILLED SOIL POROSITY (θ_a)

Air-filled soil porosity is the most significant soil parameter affecting the final steady-state flux of volatile contaminants from soil. The higher the air-filled soil porosity, the greater the emission flux of volatile constituents. (USEPA 1996a). USEPA used an air-filled porosity of 0.28 (v/v) for loam soil, its default soil texture. The Department default soil texture is sandy loam, and a default air-filled soil porosity of 0.18 (v/v) was determined as the difference between the total porosity (0.41 (v/v)) and the soil moisture content (0.23 (v/v)). The appropriate values for these two latter parameters were determined as follows:

Total soil porosity

The Department obtained the value of 0.41(v/v) for total soil porosity for sandy loam soil, from Carsel and Parrish (1988), which is one of the data sources cited by the USEPA in the soil screening guidance.

Soil moisture content

Soil moisture contents is highly specific to soil type and climate (Sanders and Talimcioglu, 1997). The moisture content will vary according to season and short-term weather. In New Jersey, this variation for a sandy loam soil has been estimated to lie within the range of 0.18 to 0.26 (v/v) (Sanders and Talimcioglu, 1997). For purposes of the New Jersey generic remediation standard calculation, it is best to use local climate data to determine average water content for a targeted soil. USEPA's soil moisture value corresponds to a moisture level in between the field capacity of sandy loam soils and the saturation volume for loam soils, and is higher than the actual average moisture level for sandy loam soil in New Jersey (Sanders and Talimcioglu, 1997). For New Jersey, an average soil moisture content specific to sandy loam soil and New Jersey climate and weather conditions was calculated using a simple relationship described in the USEPA SSG User's Guide (USEPA, 1996b). A value of 0.23 (v/v) was calculated. Appendix D contains additional information regarding determination of the generic soil moisture level.

SOIL-WATER PARTITION COEFFICIENT (K_d)

The soil organic carbon-water partition coefficient (K_{oc}) and the organic carbon content of soil (f_{oc}) are multiplied to get the soil-water partition coefficient, K_d (Equation 5). K_{oc} values were taken primarily from USEPA 1996a (see Appendix E). Regarding the fraction organic carbon content (f_{oc}), the NJDEP deviates from USEPA's default value of 0.006. The reason for this is that the Jury model calculates contaminant transport for the entire soil column, using a single value for f_{oc} . Using a surface default value of 0.006 in the model may be appropriate for the surface layer of the soil column, but may underestimate volatile migration in the subsurface portion of the soil column. Therefore, to provide a conservative (maximum) estimate of contaminant volatilization, the USEPA subsurface default value for f_{oc} (0.002) was used instead of the surface default value (0.006). This latter value does not represent typical soil organic carbon values in the subsurface, and would reduce the extent of contaminant volatilization.

APPARENT DIFFUSIVITY (D_A)

Apparent diffusivity is derived using the Equation 4. Most of the values for diffusivity in air (D_i) and diffusivity in water (D_w) are taken directly from Table 37 in USEPA 1996b. The dimensionless Henry's Law Constant (H') for most of the chemicals were taken from USEPA (1996b), Table 36. See Appendix E for specific values and sources.

VOLATILIZATION FACTOR (VF)

The soil-to-air volatilization factor, (VF), defines the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air, taking into consideration chemical-specific properties and soil characteristics. The equation for VF is based on the volatilization model developed by Jury et al. (1984) for infinite sources.

INVERSE CONCENTRATION AT CENTER OF SOURCE (Q/C)

Dispersion of a contaminant in the air was determined by modeling a square area source of one quarter-acre with a unit emission rate of one gram per second. The normalized concentration at or near the center of the square area was found to represent the maximum annual average concentration. However, when using this technique, there is an exponential relationship in which

the emission flux decreases as the site size increases. Therefore, rather than directly using the normalized concentration as a dispersion coefficient, the inverse concentration, or Q/C, was developed so as to be equally protective regardless of what the size of the site. The Q/C is simply the average rate of contaminant flux ($\text{g}/\text{cm}^2\text{-s}$) based on an overall site emission rate of one gram per second divided by the maximum normalized air concentration in kg/m^3 . Results from dispersion modeling by the Department with the Industrial Source Complex Short-Term (ISCST3) dispersion model and site-specific surface meteorological observations from Newark International Airport produce a Q/C value of $117 \text{ g}/\text{m}^2\text{-sec}$ per kg/m^3 for a quarter-acre site. Although this is the least conservative Q/C value of the three locations with meteorological data representative of New Jersey, it was chosen because most of the sites requiring remediation are closest to Newark. In addition, the higher Q/C offsets some of the conservatism inherent in the air dispersion modeling.

Table 2 Volatile Exposure Input Parameters			
Parameters		Value	Source
THQ	target hazard quotient	1	USEPA (1996a)
TR	target cancer risk	1×10^{-6}	USEPA (1996a); NJSA 58:10-1 et seq.
AT	averaging time	Carcinogenic: 70 years	USEPA (1996a)
		Noncarc./Residential: 30 years	USEPA (1996a)
		Noncarc./Nonresidential: 25 years	USEPA (2001)
EF	exposure frequency	Residential: 350 days/year	USEPA (1996a)
		Nonresidential: 225 days/year	USEPA (2001)
ED	exposure duration	Residential: 30 years	USEPA (1996a)
		Nonresidential: 25 years	USEPA (2001)
Q/C	inverse concentration at center of source	$117 (\text{g}/\text{m}^2\text{-s})/(\text{kg}/\text{m}^3)$	This document Section III.B
T	exposure interval	Residential: 9.5×10^8 seconds	USEPA (1996a)
		Nonresidential: 7.9×10^8 seconds	USEPA (2001)
ρ_b	dry soil bulk density	$1.5 \text{ g}/\text{cm}^3$	USEPA (1996a)

θ_a	air -filled soil porosity	0.18 L air/L soil	This document Section III.B
θ_w	water-filled soil porosity	0.23 L water/L soil	
n	total soil porosity	0.41 L pore/L soil	Carsel and Parrish (1988)
f_{oc}	organic carbon content of soil	0.002 g/g	This document Section III. B

C. Soil Saturation Limit (C_{sat})

The soil saturation concentration (C_{sat}) corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., nonaqueous phase liquids (NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures (USEPA 1996a).

To determine soil saturation limit for each contaminant, the Department used Equation 7. For chemical-specific values for solubility in water (S), see chemical properties table in Appendix E. The soil characteristics are the same as those used above to calculate risk-based soil remediation standards.

USEPA recommends that when the risk-based inhalation soil screening level is calculated using Equations 5 or 6, exceeds C_{sat} for liquid compounds, the soil screening level should be set at C_{sat} . For chemicals that are solid at ambient soil temperatures, when inhalation soil remediation standards are above C_{sat} , USEPA recommends that the soil cleanup decisions should be based on another pathway of concern (USEPA 1996a).

Equation for Calculating Soil Saturation Limit (C_{sat}):

$$C_{sat} = \frac{S}{\rho_b} \left[(K_d \times \rho_b) + \theta_w + (H' \times \theta_a) \right] \quad \text{Equation 7}$$

- C_{sat} = Soil saturation concentration (mg/Kg)
 S = Solubility in water (mg/L water) - *chemical-specific*
 ρ_b = Dry soil bulk density (g/cm³) – Table 3
 K_d = Soil-Water partition coefficient (cm³/g)
 θ_a = Air-filled soil porosity (L air/L soil)
 θ_w = Water-filled soil porosity (L water/L soil) – Table 3
 H' = Henry's Law Constant (unitless) - *chemical-specific*

Table 3			
Soil Saturation Input Parameters			
Parameter		Value	Source
ρ_b	Dry soil bulk density	1.5 g/cm ³	USEPA (1996a)
θ_w	Water-filled soil porosity	0.23 L water/L soil	This document Section III.B

The USEPA recommends the regulation of contaminants at the C_{sat} level because of concerns about the presence of liquid, free product. The Department also has similar concerns, but liquid, free product remediation is addressed within the context of other rules and regulations, such as the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) and the Ground Water Quality Standards (N.J.A.C. 7:9-6).

What this means is when C_{sat} is exceeded by a calculated standard for a liquid contaminant, the calculated values can not be achieved and therefore the compound can not be regulated via this exposure pathway. Therefore, the C_{sat} number will not be specified as the InhSRS. However, this is not the case for the evaluation of those liquid chemicals as particulates (where the chemical is adsorbed to airborne dust particles). Consequently, the particulate standard values

may be above C_{sat} , but as long as they do not exceed 10^6 parts per million, the calculated values will be used as the generic standard for the inhalation pathway.

IV. The Development of Generic Inhalation Standards for Particulates

A. Residential Calculations

For the residential exposure scenario, the Department utilizes the methodology for calculating inhalation soil screening levels for particulates from residential exposure from USEPA's Soil Screening Guidance: Technical Background Document (1996a). The residential soil screening level relates soil concentrations of a contaminant to harmful emissions from wind erosion only. The default site size of one-quarter acre is used to calculate the generic residential Inh_pSRS .

Equations for Calculating Inhalation Soil Remediation Standards (Residential) for Particulates:

Carcinogens

$$\text{Inh}_p\text{SRS}_c = \frac{TR \times AT \times 365 \text{ days/year}}{URF \times 1,000 \text{ ug/mg} \times EF \times ED \times \left(\frac{1}{PEF} \right)} \quad \text{Equation 8}$$

Noncarcinogens

$$\text{Inh}_p\text{SRS}_n = \frac{THQ \times AT \times 365 \text{ days/year}}{EF \times ED \times \left(\frac{1}{RfC} \right) \times \left(\frac{1}{PEF} \right)} \quad \text{Equation 9}$$

Inh_pSRS_c = Inhalation Soil Remediation Standard for carcinogens (mg/kg)

Inh_pSRS_n = Inhalation Soil Standard for noncarcinogens (mg/kg)

TR = Target cancer risk (unitless)

AT = Averaging time (years)

URF = Inhalation unit risk factor ($\mu\text{g}/\text{m}^3$)⁻¹

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

PEF = Particulate emission factor (m^3/kg)

THQ = Target hazard quotient (unitless)
RfC = Inhalation reference concentration ($\mu\text{g}/\text{m}^3$)

Equation for Calculating the Particulate Emission Factor (PEF):

$$PEF = Q/C \times \left(\frac{3,600 \text{ sec/hr}}{0.036 \times (1 - v) \times \left(\frac{U_m}{U_t} \right)^3 \times F(x)} \right) \quad \text{Equation 10}$$

PEF = Particulate emission factor (m^3/kg)
Q/C = Inverse concentration at center of source ($\text{g}/\text{m}^2\text{-s}/(\text{kg}/\text{m}^3)$)
V = Fraction of vegetative cover (unitless)
U_m = Mean annual wind speed (m/s)
U_t = Equivalent threshold value of wind speed at 7 m (m/s)
F(x) = Function dependent on U_m/U_t derived using Cowherd et al. (1985)
(unitless)

B. Residential Default Input Parameters

The emissions in the Particulate Emission Factor (PEF) equation above are based on the “unlimited reservoir” model from Cowherd et al. (1985) which was developed to estimate particulate emissions due to wind erosion. The unlimited reservoir model is sensitive to the threshold friction velocity, which is a function of particle size distribution. The threshold friction velocity has the greatest effect on emissions and resulting concentration. For this reason, a conservative soil aggregate size of 500 μm was selected as the default value for calculating generic Inh_pSRS . The soil size aggregate is related to how much wind is needed before dust is generated at a site. A soil aggregate size of 500 μm yields a threshold friction velocity of 0.5 m/s. This means that the wind speed must be at least 0.5 m/s before any fugitive dust is generated (Cowherd et al., 1985). However, the threshold friction velocity should be corrected to account for the presence of nonerodible elements. Nonerodible elements are described in Cowherd et al. (1985) as clumps of grass or stones larger than 1 cm in diameter that can deflect a wind which otherwise would impact erodible soil. The amount of vegetative cover assumed for

wind erosion was 50%, as a reasonable compromise between no vegetation and complete cover. This is not a conservative value since a significant number of sites have less than 50 percent vegetative cover. Please note that an assessment of the potential impact of some of these parameters is in Appendix F.

Exposure via the inhalation pathway was determined by modeling a square area source of one-quarter acre with a unit emission rate of one gram per second. A normalized concentration at or near the center of the square area was found to represent the maximum annual average concentration. When using this technique, there is an exponential relationship in which the emission flux decreases as the site size increases. Therefore, rather than directly using the normalized concentration as a dispersion coefficient, the inverse concentration, or Q/C , was developed so as to be equally protective regardless of what the size of the site. The Q/C is simply the average rate of contaminant flux ($\text{g}/\text{cm}^2\text{-s}$) based on an overall site emission rate of one gram per second divided by the maximum normalized air concentration in kg/m^3 .

Meteorological conditions (i.e., the intensity and frequency of wind) affect both the dispersion and emissions of particulate matter. In developing the generic InhSRS for a quarter-acre site, dispersion modeling was done with Newark International Airport meteorological observations which resulted in a Q/C value of $117 (\text{g}/\text{m}^2\text{-s})/(\text{kg}/\text{m}^3)$. This is the least conservative value of three locations with meteorological data representative of New Jersey. Since the Q/C accounts for the average concentration from wind erosion over an entire year, it should be used only to develop chronic health criteria. The ratio of emissions to maximum concentration is not appropriate to evaluate the potential for acute health criteria.

<p style="text-align: center;">Table 4 Residential Exposure Parameters</p>
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Parameters		Input Value	Source
Q/C	Inverse concentration at center of source	117 (g/m ² -s)/(kg/m ³)	This document Section IV.B
V	Fraction of vegetative cover	50 %	USEPA (1996a)
U_m	Mean annual wind speed	4.56 m/s	NOAA (2002b)
U_t	Equivalent threshold wind speed at 7 m	11.32 m/s	USEPA (1996a)
F(x)	Function of wind speed over threshold wind speed	0.159	This document Section IV.A
AT	Averaging time	Carcinogen: 70 years	USEPA (1996a)
		Noncarcinogen: 30 years	
EF	Exposure frequency	350 days	USEPA (1996a)
ED	Exposure duration	30 years	USEPA (1996 a)

C. Nonresidential Calculations

Because the methodology used for calculating a residential InhSRS for particulate contamination (particulates) could not be adapted for calculating a nonresidential inhalation soil standard, another methodology, taken from Finley and Proctor (1996), was used. Following are the equations comprising this methodology.

Equations for Calculating Inhalation Soil Remediation Standards (Nonresidential Sites 2 Acres or Larger) for Particulates:

Carcinogens

$$Inh_p SRS_c = \frac{TR}{CSF \times DOSE} \times \frac{10^6 mg}{kg} \quad \text{Equation 11}$$

Noncarcinogens

$$\text{Inh}_p\text{SRS}_n = \frac{1}{\text{DOSE} / \text{RfD}} \times \frac{10^6 \text{ mg}}{\text{kg}} \quad \text{Equation 12}$$

Inh_pSRS_c = Health-based soil cleanup level for carcinogens (mg/kg)

Inh_pSRS_n = Health-based soil cleanup level for noncarcinogens (mg/kg)

TR = Target risk (1 x 10⁻⁶)

CSF = Cancer slope factor (mg/kg-day)⁻¹

DOSE = Exposure dose calculation (mg/kg-day)

RfC = Reference concentration (µg/m³)

BW = Body Weight (70 kg)

IR = Inhalation Rate (20 m³/8-hour day)

Equation for Converting Unit Risk Factor to Cancer Slope Factor

$$\text{CSF} = \frac{\text{URF} \times \text{BW}}{\text{DIR}} \times \frac{10^3 \mu\text{g}}{\text{mg}} \quad \text{Equation 13}$$

CSF = Cancer Slope Factor (mg/kg-day)⁻¹

URF = Unit Risk Factor (ug/m³)⁻¹

BW = Body weight (70 kg)

DIR = Daily inhalation rate (20 m³/day)

Equation for Converting Reference Concentration to Reference Dose:

$$RfD = RfC \times DIR \times \left(\frac{1}{BW} \right) \times \left(\frac{mg}{10^3 \mu g} \right) \quad \text{Equation 14}$$

RfD = Reference dose (mg/kg-day)
RfC = Reference concentration ($\mu\text{g}/\text{m}^3$)
BW = Body weight (70 kg)
DIR = Daily inhalation rate (20 m^3/day)

Equation for Calculating the Exposure Dose:

$$DOSE = \frac{PEF \times IR \times EF \times ED}{BW \times AT} \quad \text{Equation 15}$$

DOSE = Exposure dose calculation (mg/kg-day)
PEF = Particulate emission factor (mg/m^3)
IR = Inhalation rate (m^3/day)
EF = Exposure frequency (days at site per year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Equation for Calculating the Particulate Emission Factor:

$$PEF = D_{isc} \times ER \times CF \times \left(\frac{A_{traf}}{As} \right) \quad \text{Equation 16}$$

PEF = Particulate emission factor (mg/m^3)
D_{isc} = Air dispersion factor for unit emission rate of 1 g/s ($\mu\text{g}\cdot\text{sec}/(\text{m}^3\cdot\text{g})$)

A_{traf}	= Area of traffic (m ²)
As	= Site area (m ²)
CF	= Conversion factor (10 ⁻³ mg/μg)
ER	= Particulate emission rate (g/s)

Equation for Calculating the Particulate Emission Rate:

$$ER = \frac{E_{10} \times TC \times D \times TF}{(28,800 \text{ seconds/8 - hr day}) \times EF}$$

Equation 17

ER	= Particulate emission rate (g/s)
E₁₀	= Particulate emission factor (g/VKT)
TC	= Daily traffic count for the unpaved area (vehicles/day)
D	= Average distance a vehicle travels through the unpaved area (km)
TF	= Traffic frequency (days with traffic/year)
EF	= Exposure frequency (days at site per year)

Equation for Calculating the Particulate Emission Factor:

$$E_{10} = (281.9 \text{ g/VKT}) \times \left[\frac{k \times (s/12)^{0.8} \times (W/3)^{0.4}}{(M/0.2)^{0.3}} \right] \times \left[\frac{(365 - p)}{365 \text{ days}} \right]$$

Equation 18

E₁₀	= Particulate emission factor (g/VKT)
k	= Particle size multiplier (unitless)
s	= Silt content of unpaved surface (%)
W	= Mean vehicle weight (tons)
M	= Surface material moisture content (%)
p	= days with at least 0.254 mm (0.01 in) of precipitation per year

Equations for Calculating InhSRS (Nonresidential Sites Less Than 2 Acres) for Particulates:

For nonresidential sites less than 2 acres in size, with little or no vehicle traffic, the same methodology used to calculate soil cleanup levels for residential sites is applied. Both Equation 8 for calculating the inhalation remediation standard for carcinogens and Equation 9 for calculating the inhalation remediation standard for noncarcinogens are used. However, the exposure frequency, exposure duration, and averaging time are adjusted to represent a worker's exposure parameters. Equation 10 is used to estimate the Particulate Emission Factor (PEF) with the only difference being the input value for Q/C. The Q/C for a 2 acre site is $85.4 \text{ (g/m}^2\text{-s)/(kg/m}^3\text{)}$. The nonresidential exposure parameters for a site less than 2 acres and affected by wind erosion only are listed in Table 6.

D. Nonresidential Default Input Parameters

The inputs used by the Department in the above equations are either USEPA default inputs, parameters provided by Proctor and Scott (1997), or New Jersey-specific values developed by the Department. Tables 5 and 6 show the input values and sources used to calculate the nonresidential InhSRS. Sensitivity analyses for a number of the inputs were done; Appendix F details the findings.

Site size is a major factor affecting the dispersion modeling results. Currently, the Department considers a site size of two acres for nonresidential exposure. The larger the site, the less stringent the Inh_pSRS, assuming that the number of vehicles and distance traveled are unchanged. In other words, when a source of emissions are dispersed over a larger area, the average concentration of contaminated dust in the air is smaller. Other factors influencing emissions are the silt content and soil moisture content of the soil. The mean silt content of 11% used is USEPA's value for publicly accessible unpaved dirt roads. The USEPA default minimum soil moisture content of 0.2% (USEPA, 1998a) was used. The Department is currently evaluating the feasibility of substituting site-specific values for soil type. However, until such data are available in a statistically large enough data set, the USEPA defaults will continue to be used. The 121.3 days with more than 0.254 mm (0.01 inch) of measurable precipitation represents Newark's thirty-year average of precipitation days in a year.

The particulate emission factor is calculated with the ISCST3 dispersion model, utilizing the particulate emission rate, ER, and the average annual concentration of resuspended particulates. For the modeling, a normalized concentration of one gram per second was assumed for the entire two-acre (8093.6 m²) square site, which, according to Department data, is the average size for a nonresidential site. The annual average concentration calculated assumes the number of possible hours (5,400 hrs) with activity at the site (this is the equivalent of 225 days). Meteorological observations from Newark International Airport were used to account for the site-specific wind intensity and frequency in New Jersey.

While a worker will not be exposed 5,400 hours per year, their eight-hour workday of exposure may occur at different times of the day. Air dispersion varies with time of day; and, it is unclear what eight-hour period of a day a worker's shift would occur. Therefore, all 24 hours for each of the selected 225 days was modeled in order to obtain a true average annual concentration for use in the particulate emission factor. The exposure of a common worker is then estimated by applying a ratio of 8/24 to the particulate emission factor.

In calculating ER (in Equation 17), it was assumed that a worker at a nonresidential site would be exposed to particulate emissions for a maximum of eight hours per day. An inhalation rate of 20 cubic meters over the eight hours is assumed (USEPA 1991b). This value reflects an inhalation rate of 2.5 cubic meters per hour for heavy activity by an outdoor worker (USEPA 1997b). As for all lifetime, or long-term (i.e., 25 years), exposure estimates, an average body weight of 70 kg was assumed (USEPA 1991b).

The default mean vehicle weight is 17 Mg (18.7 short tons). This is a nominal estimate of the average weight (i.e., empty and full) of an eighteen-wheeled semi-tractor trailer. A daily traffic count of 25 vehicle trips was assumed. This average vehicle count is based on site-specific data provided by Proctor and Scott (1997). The average distance of 0.09 km traveled represents the distance of one side of a square two-acre site.

The following method was used to estimate daily truck traffic for the state of New Jersey. Traffic count data were provided by NJDOT. The most complete data set was for December 31, 2001

when vehicles were counted on 91 Highways at 201 locations. The number of vehicles for each highway was calculated by adding the totals from each of counting stations on that highway. The number of vehicles for each of the highways was then added to determine the total daily vehicles. The total number of vehicles counted on 12/31/01 was 10,275,959.

Another database provided by the NJDOT breaks down the vehicle traffic by the number of axles and also distinguishes between pickup trucks and cars. The percentage of cars and pickup trucks (89.5) was determined for all the major highways and then subtracted from 100 to yield the total percentage of trucks. The total percentage of trucks was multiplied by the total daily vehicles to yield the number of trucks per day on the highways of New Jersey. The results are below.

Total Vehicles (TV) = 10,275,959

Total Trucks (TT) = $10,275,959 \times \frac{10.5}{100}$

TT = 1,078,975 trucks

In summary the estimated number of trucks counted on New Jersey highways on 12/31/2001 was 1,078,975. It is obvious that some vehicles could have been counted more than once on the same highway or perhaps even a second highway, however with the thousands of miles of highways in the state many cars and trucks also went uncounted.

The Department next estimated the number of sites that are available for trucks to visit. The U.S. Census Bureau publishes yearly statistics describing the number of firms and establishments in the state of New Jersey. The information for 2001 was used because this matches the year the truck traffic data were compiled. One table in the census information is broken down by the number of employees per firm and is compared to the number of firms and establishments. A second table lists the types of industries and compares this with the number of firms and employees. For the Departments truck traffic estimate, only firms with 10 or more employees were counted because it was believed that smaller firms would be on smaller size sites and thus not applicable to the inhalation risk models. There are 21 industry categories listed on the

second census table noted above. Seven of the 21 categories are industries that clearly would not be applicable for the truck traffic scenario e.g. retail trade, real estate, health care, etc. The industry categories selected for this evaluation comprise 61% of the total firms in the census data. The total number of establishments with more than 10 employees on the census data table is 75,477, 61% of this number is 46,041 firms.

The estimate of the number of trucks visiting a site was made by dividing the total number of trucks from the 12/31/2001 NJDOT data by the number of applicable sites from the US Census statistics. This number is 23 trucks per site, thus the 25 trucks per site used in the model for daily truck traffic seems to be a reasonable estimate.

Equation 18 is the empirical expression used to estimate PM-10 particulate emissions per vehicle kilometer traveled on an unpaved road taken from the USEPA document AP-42, Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources (USEPA, 1998a). It is the basis for estimating nonresidential exposure from particulate emissions.

Table 5			
Nonresidential Exposure Parameters (2 Acres and Greater)			
Parameters		Input Value	Source
A_s	Site size	2 acres	This document Appendix G
s	Silt content	11%	USEPA (1998a)
W	Mean vehicle weight	17 Mg (18.7 tons)	Proctor & Scott (1997)
M	Surface material moisture content	0.2 %	USEPA (1998a)
p	Number of days with > 0.01 inch of precipitation	121.3 days	NOAA (2002b)
TC	Daily traffic count	25 vehicles	Proctor & Scott (1997)
D	Average distance traveled	0.09 km	This document Section III.D
TF	Frequency of traffic	225 days	USEPA (2001)
IR	Inhalation rate	20 m ³ /day	USEPA (1997b)
EF	Exposure frequency	225 days	USEPA (2001)

ED	Exposure duration	25 years	USEPA (2001)
BW	Body weight	70 kg	USEPA (2001)
AT	Averaging time	Carcinogen: 70 years	USEPA (2001)
		Noncarcinogen: 25 years	

Table 6 Nonresidential Exposure Parameters (Less than 2 Acres)			
Parameters		Input Value	Source
Q/C	Inverse concentration at center of source	85 g/m ² -s per kg/m ³	USEPA (1996a)
V	Fraction of vegetative cover	50 %	USEPA (1996a)
U_m	Mean annual wind speed	4.56 m/s	NOAA (2002b)
U_t	Equivalent threshold wind speed at 7 m	11.32 m/s	USEPA (1996a)
F(x)	Function of wind speed over threshold wind speed	0.159	NJDEP/BAQEv (2003)
AT	Averaging time	Carcinogen: 70 years	USEPA (2001)
		Noncarcinogen: 25 years	
EF	Exposure frequency	225 days	USEPA (2001)
ED	Exposure duration	25 years	USEPA (2001)

V. Inhalation Soil Remediation Standards

A. Calculation Results

For residential and nonresidential exposure scenarios, InhSRS were calculated for each contaminant for both particulate and volatile phases using existing carcinogenic and noncarcinogenic health endpoint toxicity data where applicable. The results of these calculations are provided in Appendix H. Note that the values in Appendix H are the raw results and have not been modified to conform to the significant figure and rounding rules established for this document. The lowest calculated standard for each given contaminant for the different exposure scenarios is highlighted in these tables. This value would be the most protective standard irrespective of whether or not the health endpoint was carcinogenic or noncarcinogenic. Three different exposure scenarios are represented in the tables. One is the typical residential exposure scenario. The other two are nonresidential exposure scenarios but are distinguished because one is applicable to sites 2 acres or larger while the other is applicable to sites less than 2 acres in size. For ease of use Table 7 summarizes the Appendix H values by presenting the proposed generic standard for each of the three exposure scenarios. These values are the lowest and therefore most protective of the calculated standards within a given exposure scenario and are irrespective of the relevant phase or health endpoint type. The values in Table 7 have been rounded and are to the appropriate number of significant figures.

B. Calculated Values

Within the inhalation pathway and for all the chemicals considered, the generic standards for the volatile organic compounds typically are more likely to lower than the generic standards developed for particulate contamination. For the residential exposure scenario, of the total 145 chemicals for which standards were to be derived, 60 were volatile based with 27 being particulate based. The remaining 58 were not regulated or had no available toxicity data to derive an appropriate InhSRS. For the nonresidential exposure scenario, 58 were volatile based while 41 were particulate based. The remaining 46 were not regulated or had no available toxicity data to derive an appropriate standard. The increase in the particulate based standards compared to volatile based standards under the nonresidential exposure scenario is in part attributable to how Csat was addressed as well as the inclusion of vehicle traffic impacts under

this exposure scenario and not the residential. Vehicle traffic produces much higher airborne particulate concentrations compared to just wind alone generated particulate concentrations. Consequently, the nonresidential exposure scenario InhSRS is much lower than the residential exposure scenario InhSRS. The implication of this is that the unrestricted use level for these particulate based InhSRS is determined by the nonresidential exposure scenario InhSRS. This differs from the typical situation in which residential standards are lower than nonresidential standards.

The calculated values derived for a carcinogenic health endpoint are similarly more critical to a remedial investigation than the corresponding noncarcinogenic health endpoint values. For the residential exposure scenario, of the 87 regulated chemicals, 64 were associated with a carcinogenic health endpoint. For the 99 regulated chemicals under the nonresidential exposure scenario, 73 were associated with a carcinogenic health endpoint.

C. Generic Soil Remediation Standards for the Inhalation Pathway

Listed in Table 7 are the InhSRS which the Department has no regulatory concern relative to the inhalation pathway for the respective residential and nonresidential exposure scenarios. Notes are provided to identify if the standard is derived from a carcinogenic or noncarcinogenic health endpoint, as well as whether or not the chemical was evaluated as a volatile or a particulate.

Appendix H contains all the calculated standards whether or not they are the generic soil remediation standards (the most conservative value for a given exposure scenario). Appendix H is provided in order to facilitate potential alternative remediation standard development. The alternative remediation standard analysis may occur both within and between pathways. Consequently, it may be necessary to evaluate more than just the generic standards. By providing all the calculated values, maximum flexibility is provided.

Table 7. Lowest Generic Soil Remediation Standards for the Inhalation Pathway

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
			mg/kg	Notes	mg/kg	Notes	mg/kg	Notes
Acenaphthene (PAH)	83-32-9	0.4	NR ¹	A ² ,B ³	NR	A,B	320,000	C ⁴ , P ⁵
Acenaphthylene (PAH)	208-96-8	0.4	NR	A,B	NR	A,B	320,000	C, P
Acetone	67-64-1	5	NR	A,B,D ⁶	NR	A,B,D	NR	A,B,D
Acetophenone	98-86-2	1	3	NC ⁷ , V ⁸	4	NC, V	4	NC, V
Acrolein	107-02-8	15	(0.07) ⁹	NC, V	(0.09)	NC, V	(0.09)	NC, V
Acrylonitrile	107-13-1	5	(1)	C, V	(2)	C, V	(2)	C, V
Aldrin	309-00-2	0.007	6	C, V	11	C, V	11	C, V
Aluminum	7429-90-5	40	NR	B,NV ¹⁰	NR	B,NV	NR	B,NV
Anthracene (PAH)	120-12-7	0.4	380,000	C, P	560,000	C, P	32,000	C, P
Antimony	7440-36-0	12	350,000	NC, P	440,000	NC, P	25,000	NC, P
Arsenic	7440-38-2	3	960	C, P	1,400	C, P	81	C, P
Atrazine	1912-24-9	430	NR	A,B	NR	A,B	NR	A,B
Barium	7440-39-3	40	880,000	NC, P	NR	B,NV	62,000	NC, P
Benzaldehyde	100-52-7	0.1	NR	A,B	NR	A,B	NR	A,B
Benzene	71-43-2	0.4	2	C, V	4	C, V	4	C, V
Benzidine	92-87-5	4	(0.006)	C, V	(0.01)	C, V	(0.01)	C, V
Benz(a)anthracene (PAH)	56-55-3	0.4	38,000	C, P	56,000	C, P	3,200	C, P

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Benzo(a)pyrene (PAH)	50-32-8	0.5	3,800	C, P	5,600	C, P	320	C, P
Benzo(b)fluoranthene (PAH)	205-99-2	0.5	38,000	C, P	56,000	C, P	3,200	C, P
Benzo(g,h,i)perylene (PAH)	191-24-2	0.5	380,000	C, P	560,000	C, P	32,000	C, P
Benzo(k)fluoranthene (PAH)	207-08-9	0.5	38,000	C, P	56,000	C, P	3,200	C, P
Beryllium	7440-41-7	1	1,700	C, P	2,500	C, P	150	C, P
1,1-Biphenyl	92-52-4	1	NR	A,B	NR	A,B	NR	A,B
Bis(2-chloroethyl)ether	111-44-4	0.5	0.7	C, V	1	C, V	1	C, V
Bis(2-chloroisopropyl)ether	108-60-1	0.5	30	C, V	51	C, V	51	C, V
Bis(2-ethylhexyl)phthalate	117-81-7	0.5	NR	A,B	NR	A,B	150,000	C, P
Bromodichloromethane	75-27-4	0.5	1	C, V	2	C, V	2	C, V
Bromoform	75-25-2	0.7	130	C, V	210	C, V	210	C, V
Bromomethane (Methyl bromide)	74-83-9	1	32	NC, V	45	NC, V	45	NC, V
2-Butanone (Methyl Ethyl Ketone)	78-93-3	3	NR	A,B	NR	A,B	NR	A,B
Butylbenzyl phthalate	85-68-7	0.4	NR	A,B	NR	A,B	NR	A,B
Cadmium	7440-43-9	1	980	C, P	1,500	C, P	83	C, P
Caprolactum	105-60-2	0.4	NR	A,B	NR	A,B	NR	A,B
Carbazole	86-74-8	0.2	720,000	C, P	NR	A,B	61,000	C, P

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Carbon disulfide	75-15-0	0.6	NR	A,B	NR	A,B	NR	A,B
Carbon tetrachloride	56-23-5	1	(0.8)	C, V	1	C, V	1	C, V
Chlordane (alpha + beta)	57-74-9	0.08	41,000	C, P	61,000	C, P	3,500	C, P
4-Chloroaniline	106-47-8	0.8	NR	A,B	NR	A,B	NR	A,B
Chlorobenzene	108-90-7	0.3	NR	A,B	NR	A,B	NR	A,B
Chloroethane (Ethyl chloride)	75-00-3	0.8	NR	A,B	NR	A,B	NR	A,B
Chloroform	67-66-3	0.4	0.8	C, V	1	C, V	1	C, V
Chloromethane (Methyl chloride)	74-87-3	0.8	5	C, V	9	C, V	9	C, V
4-Chloro-3-methyl phenol	59-50-7	none	NT ¹¹		NT		NT	
2-Chlorophenol	95-57-8	0.8	1,200	NC, V	1,600	NC, V	1,600	NC, V
Chrysene (PAH)	218-01-9	0.4	380,000	C, P	560,000	C, P	32,000	C, P
Cobalt	7440-48-4	10	8,800	NC, P	11,000	NC, P	620	NC, P
Copper	7440-50-8	5	35,000	NC, P	44,000	NC, P	2,500	NC, P
Cyanide	57-12-5	1	NR	NV,B	NR	NV,B	NR	NV,B
4,4'-DDD (p,p'-TDE)	72-54-8	0.007	60,000	C, P	89,000	C, P	5,100	C, P
4,4'DDE (p,p'-DDX)	72-55-9	0.007	870	C, V	63,000	C, P	3,600	C, P
4,4'-DDT	50-29-3	0.008	42,000	C, P	63,000	C, P	3,600	C, P
Dibenz(a,h)anthracene (PAH)	53-70-3	0.5	3,400	C, P	5,100	C, P	290	C, P

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Dibenzofuran	132-64-9	none	NT		NT		NT	
Dibromochloromethane	124-48-1	0.4	4	C, V	6	C, V	6	C, V
1,2-Dibromo-3-chloropropane	96-12-8	2	(0.1)	C, V	(0.2)	C, V	(0.2)	C, V
1,2-Dibromoethane	106-93-4	0.6	(0.3)	C, V	0.6	C, V	0.6	C, V
1,2-Dichlorobenzene (o-)	95-50-1	0.4	NR	A,B	NR	A,B	NR	A,B
1,3-Dichlorobenzene (m-)	541-73-1	0.7	NR	A,B	NR	A,B	NR	A,B
1,4-Dichlorobenzene (p-)	106-46-7	0.4	6	C, V	10	C, V	10	C, V
3,3'-Dichlorobenzidine	91-94-1	1	4	C, V	18,000	C, P	1,000	C, P
Dichlorodifluoromethane	75-71-8	0.6	NR	A,B	NR	A,B	NR	A,B
1,1-Dichloroethane	75-34-3	0.4	370	NC, V	510	NC, V	510	NC, V
1,2-Dichloroethane	107-06-2	0.5	19	C, V	32	C, V	32	C, V
1,1-Dichloroethene	75-35-9	0.7	(0.4)	C, V	(0.6)	C, V	(0.6)	C, V
cis-1,2-Dichloroethene	156-59-2	0.8	300	NC, V	420	NC, V	420	NC, V
trans-1,2-Dichloroethene	156-60-5	0.5	390	NC, V	540	NC, V	540	NC, V
2,4-Dichlorophenol	120-83-2	0.5	NR	A,B	NR	A,B	NR	A,B
1,2-Dichloropropane	78-87-5	0.5	2	C, V	4	C, V	4	C, V
1,3-Dichloropropene (cis and trans)	542-75-6	0.6	3	C, V	5	C, V	5	C, V

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Dieldrin	60-57-1	0.007	2	C, V	3	C, V	3	C, V
Diethylphthalate	84-66-2	0.4	NR	A,B,D	NR	A,B,D	NR	A,B,D
2,4-Dimethyl phenol	105-67-9	0.9	NR	A,B	NR	A,B	NR	A,B
Dimethyl phthalate	131-11-3	0.4	NT		NT		NT	
Di-n-butyl phthalate	84-74-2	0.5	NR	A,B,D	NR	A,B,D	NR	A,B,D
4,6-Dinitro-2-methylphenol	534-52-1	1	710,000	NC, P	870,000	NC, P	50,000	NC, P
2,4-Dinitrophenol	51-28-5	1	NR	A,B	NR	A,B	870,000	NC, P
2,4-Dinitrotoluene	121-14-2	0.5	7	C, V	12	C, V	12	C, V
2,6-Dinitrotoluene	606-20-2	0.5	3	C, V	9	C, P	0.5	C, P
Di-n-octylphthalate	117-84-0	0.5	NR	A,B,D	NR	A,B,D	NR	A,B,D
1,2-Diphenylhydrazine	122-66-7	0.2	6	C, V	10	C, V	10	C, V
Endosulfan I & II	115-29-7	0.008	NR	A,B	NR	A,B	NR	A,B
Endosulfan sulfate	1031-07-8	0.01	NR	A,B	NR	A,B	NR	A,B
Endrin	72-20-8	0.007	NR	A,B	NR	A,B	120,000	C, P
Ethylbenzene	100-41-4	0.4	NR	A,B	NR	A,B	NR	A,B
Fluoranthene (PAH)	206-44-0	0.4	NR	A,B	NR	A,B	320,000	C, P
Fluorene (PAH)	86-73-7	0.4	NR	A,B	NR	A,B	320,000	C, P
a-HCH (a-BHC)	319-84-6	0.007	0.9	C, V	1	C, V	1	C, V

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
b-HCH (b-BHC)	319-85-7	0.007	7,800	C, P	12,000	C, P	660	C, P
Heptachlor	76-44-8	0.007	0.2	C, V	0.4	C, V	0.4	C, V
Heptachlor epoxide	1024-57-3	0.008	6	C, V	10	C, V	10	C, V
Hexachlorobenzene	118-74-1	0.6	2	C, V	3	C, V	3	C, V
Hexachloro-1,3-butadiene	87-68-3	0.5	16	C, V	26	C, V	26	C, V
Hexachlorocyclopentadiene	77-47-4	0.6	58	NC, V	81	NC, V	81	NC, V
Hexachloroethane	67-72-1	0.5	110	C, V	180	C, V	180	C, V
2-Hexanone	591-78-6	2	NR	E ¹² ,B	NR	E,B	NR	E,B
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	0.5	38,000	C, P	56,000	C, P	3,200	C, P
Isophorone	78-59-1	0.5	NR	A,B	NR	A,B	NR	A,B
Lead	7439-92-1	2	180,000	NC, P	220,000	NC, P	12,000	NC, P
Lindane (g-HCH) (g-BHC)	58-89-9	0.006	4	C, V	7	C, V	7	C, V
Manganese	7439-96-5	3	88,000	NC, P	110,000	NC, P	6,300	NC, P
Mercury	7439-97-6	0.1	36	NC, V	50	NC, V	50	NC, V
Methoxychlor	72-43-5	0.01	NR	A,B	NR	A,B	NR	A,B
Methyl acetate	79-20-9	0.4	NR	A,B	NR	A,B	NR	A,B
Methylcyclohexane	108-87-2	none	NR	A,B	NR	A,B	NR	A,B
Methylene chloride	75-09-2	0.4	44	C, V	74	C, V	74	C, V

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
4-Methyl-2-pentanone (MIBK)	108-10-1	1	NR	A,B	NR	A,B	NR	A,B
2-Methylphenol (o-cresol)	95-48-7	0.5	14,000	NC, V	20,000	NC, V	20,000	NC, V
4-Methylphenol (p-cresol)	106-44-5	0.6	NR	A,B	NR	A,B	NR	A,B
Methyl tert butyl ether (MTBE)	1634-04-4	0.8	140	C, V	240	C, V	240	C, V
Naphthalene	91-20-3	0.8	34	NC, V	48	NC, V	48	NC, V
Nickel	7440-02-0	8	350,000	NC, P	440,000	NC, P	25,000	NC, P
2-Nitroaniline	88-74-4	2	50	NC, V	70	NC, V	70	NC, V
Nitrobenzene	98-95-3	0.5	210	NC, V	300	NC, V	300	NC, V
4-Nitrophenol	100-02-7	none	NT		NT		NT	
N-Nitrosodimethylamine	62-75-9	0.5	(0.02)	C, V	(0.04)	C, V	(0.04)	C, V
N-Nitrosodi-n-propylamine	621-64-7	0.4	(0.2)	C, V	0.4	C, V	0.4	C, V
N-Nitrosodiphenylamine	86-30-6	0.5	NR	A,B	NR	A,B	140,000	C, P
PCBs (Polychlorinated biphenyls)	1336-36-3	0.8	26	C, V	44	C, V	44	C, V
Pentachlorophenol	87-86-5	2	280	C, V	460	C, V	460	C, V
Phenanthrene (PAH)	85-01-8	0.4	NR	A,B	NR	A,B	320,000	C, P
Phenol	108-95-2	0.5	NR	A,B	NR	A,B	NR	A,B
Pyrene (PAH)	129-00-0	0.4	NR	A,B	NR	A,B	320,000	C, P
Selenium	7782-49-2	7	NR	NV,B	NR	NV,B	NR	NV,B

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Silver	7440-22-4	2	NR	NV,B	NR	NV,B	NR	NV,B
Styrene	100-42-5	0.3	120	C, V	200	C, V	200	C, V
Tertiary butyl alcohol (TBA)	75-65-0	10	5,700	NC, V	8,000	NC, V	8,000	NC, V
1,1,2,2-Tetrachloroethane	79-34-5	0.3	1	C, V	2	C, V	2	C, V
Tetrachloroethene (PCE)	127-18-4	0.7	2	C, V	4	C, V	4	C, V
Thallium	7440-28-0	5	370,000	NC, P	460,000	NC, P	26,000	NC, P
Toluene	108-88-3	0.5	NR	A,B	NR	A,B	NR	A,B
Toxaphene	8001-35-2	0.3	90	C, V	150	C, V	150	C, V
1,2,4-Trichlorobenzene	120-82-1	0.6	NR	A,B	NR	A,B	NR	A,B
1,1,1-Trichloroethane	71-55-6	0.5	NR	A,B	NR	A,B	NR	A,B
1,1,2-Trichloroethane	79-00-5	0.5	3	C, V	4	C, V	4	C, V
Trichloroethene (TCE)	79-01-6	0.8	9	C, V	15	C, V	15	C, V
Trichlorofluoromethane	75-69-4	0.6	NR	A,B	NR	A,B	NR	A,B
2,4,5-Trichlorophenol	95-95-4	0.6	NR	A,B	NR	A,B	NR	A,B
2,4,6-Trichlorophenol	88-06-2	0.5	280	C, V	480	C, V	480	C, V
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.4	NR	A,B	NR	A,B	NR	A,B
Vanadium	7440-62-2	10	NR	NV,B	NR	NV,B	NR	NV,B

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Nonresidential Standards			
			mg/kg	Notes	Less than 2 Acres		2 or More Acres	
					mg/kg	Notes	mg/kg	Notes
Vinyl chloride	75-01-4	0.8	0.9	C, V	1	C, V	1	C, V
Xylenes	1330-20-7	1	NR	A,B	NR	A,B	NR	A,B
Zinc	7440-66-6	12	NR	NV,B	NR	NV,B	110,000	NC, P

- (1) NR means the chemical is not regulated by the Department for the inhalation pathway and for the specified exposure scenario. The reasons are identified in the "Notes" in the adjacent column.
- (2) A means the health based soil remediation standard for a volatile compound exceeds Csat.
- (3) B means that the calculated health based soil remediation standard for a compound in a particulate phase exceeds one million parts per million
- (4) C means the chemical was evaluated a carcinogen.
- (5) P means the chemical was evaluated as a particulate.
- (6) D means that the calculated health based soil remediation standard for a volatile compound exceeds one million parts per million.
- (7) NC means the chemical was evaluated as a noncarcinogen.
- (8) V means the chemical was evaluated as a volatile.
- (9) Values within parentheses denote standards that defer to the PQLs
- (10) NV means the chemical is nonvolatile.
- (11) NT means there was no toxicity data to derive a standard for the inhalation pathway and for the specified exposure scenario.
- (12) E means physical or chemical data needed for the computation as a volatile was unavailable.

VI. Methodology for Developing Alternative Remediation Standards

A. Overview

The Brownfields and Contaminated Site Remediation Act (N.J.S.A. 58:10-1 et seq.) requires the Department to consider site specific factors in determining appropriate remediation standards. For the inhalation of volatiles and particulate pathways the Department must allow the use of an alternative soil remediation standard which may be based on (1) physical site characteristics which may vary from those used by the Department in the development of the soil remediation standards adopted pursuant to this section; and (2) physical characteristics of the site, including, but not limited to, climatic conditions and topographic conditions.

The Department has developed a process described below by which alternative remediation standards (ARS) may be developed. Alternative remediation standards reflect the effect of site specific conditions on the assumptions and models used to generate the generic remediation standards.

The Department will also review other proposed approaches incorporating different models, assumptions, and information on a case by case basis. If the Department approves of their use, these may then be used to develop an acceptable ARS. However, the Department does reserve the right to unilaterally determine the acceptability of these proposals.

An acceptable ARS will effectively function as the generic InhSRS that it replaces for that particular site. Specifically, such an ARS would be used in determining whether or not an area is contaminated. The ARS would be used in the compliance process just as a generic InhSRS would be.

B. Methods to Develop ARSs for Volatile Contaminants

For volatile contaminants, only a limited number of variables are allowed to be changed to accommodate site-specific conditions. These are described below.

1. Depth Range of Contamination – The EPA SSG methodology (USEPA, 1996a) used to develop generic cleanup standards assumes an infinite depth of contamination. If the depth of contamination is known, this may be incorporated into development of alternative cleanup standards. An assumption of finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a higher remediation standard. See Appendix I for detailed instructions on how to use the EMSOFT software package to calculate ARS using the Jury model. Following the methodology in Appendix I, a site-specific volatilization factor (VF) can be derived that can be substituted into Equation 3.

2. Organic Carbon (f_{oc}) - The organic carbon content of the soil is used with a contaminant's K_{oc} value to determine the extent the contaminant is adsorbed to soil. In general, the soil remediation standard is linearly related to the organic carbon content. (For example, a doubling of the organic carbon content of the soil will double the calculated remediation standard, making it lower.) The Lloyd Kahn method is available for determination of organic carbon content of soil (USEPA, 1988). Use of the Lloyd Kahn method may be used to determine a sample-specific fraction organic carbon content, which may be substituted into Equation 5 to determine a sample-specific ARS.

C. Volatiles - Variables Not Subject to Change

For volatile contaminants, the following variables can **not** be changed to develop an ARS:

1. Total Soil Porosity (n) – Department uses 0.41 because it is the value for sandy loam soil, which is the default soil texture for New Jersey. USEPA uses default of 0.43 for loam soil. Site-specific porosity values are difficult to obtain in the field, and laboratory measurements of this parameter are not advised since the integrity of the soil structure is lost during sampling unless special techniques are used.

2. Water-filled & Air-filled Soil Porosity (Volumetric soil water content) (θ_w & θ_a) – Experimentally determining site-specific air and water contents of a soil at a particular site is

difficult, because of long-term and short-term variations in soil moisture. Long-term variations occur due to seasonal changes and short-term variations occur due to weather events. For this reason the SSG User's guide does not recommend using field results to adjust these parameters. Therefore, adjustment of these parameters will not be allowed without consultation with and approval by the Department.

3. Dry Soil Bulk Density (ρ_b) - Dry soil bulk densities vary over a relatively small range, from about 1.3-1.8 g/cc (Carsel et al., 1988). The USEPA default value was used because it agrees with the value listed for a sandy loam soil texture. Remediation standards are only slightly affected by the value for this parameter.
4. Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values (1996a).
5. Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).
6. Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).
7. Site Size – Adjustments for actual site size can not be done because the compliance mechanism uses a fixed area approach.

D. Methods to Develop ARS for Particulate Contaminants

For particulates contaminants, a limited number of variables are allowed to be changed to accommodate site-specific conditions. These are described below.

Residential

Vegetative Cover - For the residential exposure scenario a default of 50% vegetative cover was employed because it represented a reasonable compromise between no cover and a totally vegetated site. This parameter can be varied to reflect a site-specific condition and an appropriate ARS subsequently calculated. However, such an ARS, if it represented an increase over the original standard, would have to be enforced via a deed notice to ensure that the basis for the ARS remained intact. Biennial certification would consist of a letter by the property owner or appropriate designate certifying that the vegetative cover was present at the coverage used to establish the ARS.

Nonresidential

Silt Content - Silt is defined by USEPA as particles smaller than 75 micrometers (um) in diameter (USEPA, 1998a). The silt fraction is determined by measuring the proportion of loose dry surface dust that passes a 200-mesh screen, using the ASTM-C-136 method. The range of documented silt contents is 5.8% to 23.3%. The silt content of 5.8% is the composite of 63 soil samples collected from soil contaminated with chromium ore processing residue at Liberty State Park (Kitsa, et al. 1992). These soil samples were collected from 0 to 2 cm. A value of 6.4% is taken from AP-42 (USEPA 1998a) and represents the silt content for unpaved public roads with gravel/crushed limestone. A value of 10.3% is the mean silt content measured at a tractor/trailer parking facility in Hudson County (Scott et al. 1997). Eight surface soil samples (0-1cm) from this site were collected and analyzed. The silt contents for these soil samples ranged from 1.9 to 23.3%. The default silt content used to calculate the generic soil screening level is 11%. This value is from USEPA (1998a) for dirt roads (i.e., local material compacted, bladed, and crowned) and determined from 24 samples taken at 8 sites. Prior Department approval of this ARS option is required.

E. Particulates – Variables Not Subject to Change

For particulate contaminants, the following variables can **not** be changed to develop an ARS. Many of the variables are used as defaults in other Federal and State calculations. Those variables that are not calculation-standards would require widespread technical support.

Residential

1. Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values(1996a).
2. Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).
3. Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).
4. Site Size – Adjustments for actual site size can not be done because the compliance mechanism uses a fixed area approach.

Nonresidential

1. Surface material moisture content - The default surface material moisture content from AP-42 (USEPA 1998a) is 0.2%. It may not be adjusted because of the difficulty in determining a representative measure for the entire site.
2. Mean vehicle weight - The default mean vehicle weight assumed is 17 metric tons (Mg). This is a reasonable estimate of the average weight (i.e., empty and full) of an eighteen-wheeled tractor/trailer. Scott et al. (1997) also recommends a generic mean vehicle weight of 17 Mg. A site-specific vehicle weight value is too variable and not readily amendable to enforcement.
3. Number of days with greater than 0.01 inches of precipitation - The Department used 121.3 days with 0.01 inch (0.254 mm) of measurable precipitation as its default. This value represents Newark's 30-year average of precipitation days annually. The average number of precipitation days for Atlantic City and Philadelphia are 111.5 and 115.4 days, respectively, over the same 30-year period. The number of precipitation days with 0.01 inch or greater

were taken from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data Summaries (NOAA, 2002a; NOAA, 2002b; NOAA, 2002c). There is no point in changing the number of days with precipitation or other meteorological data because the Newark meteorological data produces the least conservative soil standard. Newark meteorological data was used in all of the generic InhSRS to offset some of the conservatism inherent in the air dispersion modeling.

4. Frequency of traffic - The frequency of traffic is the number of days per year that vehicle traffic occurs at a site. A value of 225 days assumes that on-site traffic occurs five days a week, 50 weeks per year. Traffic is assumed not to occur on weekends or during holidays (10 days/year), and poor weather days.
5. Averaging time - The averaging time for contaminants that are carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 25 years. These are USEPA default values (USEPA 2001).
6. Exposure frequency - The exposure frequency also assumes 225 days per year. A value of 225 days assumes a five-day work week for 50 weeks per year. Furthermore, exposure is assumed not to occur during holidays, vacation, and sick time, accounting for another 25 days during the year. These are USEPA default values (USEPA 2001).
7. Exposure duration - The exposure duration for nonresidential sites is 25 years (USEPA 2001).
8. Inhalation rate - The Department default inhalation rate for an industrial scenario is 20 cubic meters per day (USEPA 1997b). This is based on the recommended inhalation rate of 2.5 m³/hr for an outdoor worker undergoing heavy activities (USEPA 2001).
9. Body weight - The default body weight for an industrial scenario is 70 kg (USEPA 2001).

10. Number of vehicle trips per day - The default vehicle count assumed for a two-acre site is 25 vehicle trips per day. This value was obtained from counts taken at 21 Hudson County chromium ore process residue sites that currently support traffic (Proctor and Scott 1997). This is a moderate assumption, as this variable can vary significantly by industrial use and site size. For example, Scott et al. (1997) assumed a total of 40 small vehicle trips per day for a nonresidential half-acre site.
11. Size of property – Based on the analysis detailed in Appendix G. The average site size of a nonresidential site is 2 acres. Nonresidential site size can not be adjusted because the number of vehicle trips has been associated with this size. As a nonresidential site size increases it becomes more difficult to set a reasonable and worst-case number of vehicle trips per day.
12. Average distance each vehicle travels - The average distance a vehicle travels through an unpaved area is closely related to site size. As a general rule, the minimum distance traveled by a vehicle should be represented by at least the length of the longest side of the site.

VII. Compliance

Compliance is defined to be the process whereby the remedial investigation results from a site are compared against the appropriate soil remediation standards and a determination made whether or not those standards have been exceeded. If an appropriate generic standard is exceeded at any given location, complete delineation as defined by the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, is required. However, exceedance at any given location at this stage in the investigation may or may not require remediation. Further investigation and evaluation is required. Appropriate soil remediation standards may be the generic standard or an ARS developed specifically for the site.

Compliance for the inhalation pathway employs a fixed area approach. This approach will be applicable to both the volatile and particulate phase standards. Following complete horizontal and vertical delineation, a given site will be divided into “functional areas” of fixed size and a determination made if there is an exceedance of the remediation goal within those areas. If no functional area on the site exceeds the appropriate remediation standards, no further action will be required for the inhalation pathway. If there is a determination that a functional area exceeded an appropriate remediation standard, then the various remedial options must be considered for the area under evaluation.

Relative to the horizontal dimension, the functional area for residential exposure scenarios will be the default residential lot size of 0.25 acres. In the case of the nonresidential exposure scenarios, the functional area will be 2 acres, the default nonresidential site lot size. Additional information on site size can be found in Appendix G.

For those instances where Inh_pSRS are being used, if the nonresidential site size is less than 2 acres, a modification of the inhalation pathway is required. This is because the Inh_pSRS are primarily resulting from vehicle activity. The default scenario of 25 semi-tractor trailers utilizing the site on a per day basis does not seem realistic on sites smaller than 2 acres. From a physical space perspective, the presence of the vehicles themselves, the associated buildings and facilities which the vehicles service, and the space the vehicles would need in order to generate the

airborne particulates indicate that an exclusion below a minimum site size is appropriate. In these instances, only an inhalation pathway standard based on wind alone generated particulates is relevant. The appropriate standard to apply in the case of sites smaller than 2 acres is found in Table 7 as well as Appendix H (in raw form) and is subject to the limitations described.

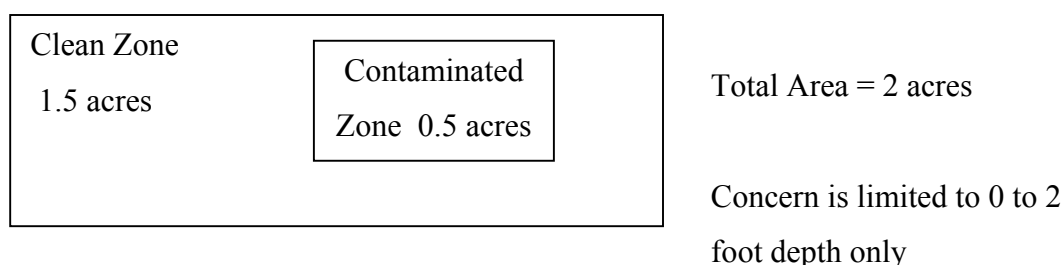
The shape of these fixed areas is rectangular, and may be varied with respect to reasonable specific dimensions. Placement and specific shape will be dictated by the distribution of the contamination. The placement and shape of the initial assessed areas must be biased to consider worst-case contamination.

The vertical dimension of each fixed area will be divided into vertical layers each 2 feet thick. Specifically, the layers will be 0 to 2 feet below ground surface (bgs), 2 to 4 feet bgs, 4 to 6 feet bgs, etc. This 2-foot layer approach reflects typical soil sampling methods conducted during remedial investigation. It should be noted that the 0 to 2 feet bgs layer will encompass both surface samples (0-6") as well as those samples taken at less than 2 feet of depth (1.5-2.0').

Within a given horizontal fixed area, as well as within a specified layer, compliance will be determined by comparison of the 95% upper confidence limit (UCL) of the mean of the selected data against the applicable standard. Each layer for each fixed area may need to be evaluated separately. However, if the worst case analysis indicates no concern, the remainder of the site does not have to be evaluated. If the sampling is deemed representative by the Department, all the data within each layer of the fixed area would be used to develop the 95% UCL of the mean of the data. However, if deemed necessary because of concerns about sampling used to improperly weight clean areas, the Department would require adjusting for the amount of "clean zone" (that volume that is below the standard) present in a layer being evaluated. This would be done by calculating a 95% UCL of the mean representing each of the "clean" and the "contaminated" portions of the functional area and weighting them according to the volumes/areas they represent. This weighted value would then compared to the applicable standard.

An example of this weighting process is described in Figure 1 below. This example uses a 2 acre site that has a 0.5 acre area of contamination (i.e., exceedance of the inhalation pathway standard of 100 mg/kg of dry weight soil). Consequently, there is a 1.5-acre clean zone. In this example contamination has been completely delineated and is determined to be limited to the 0 to 2-foot depth soil layer.

Figure 1. Hypothetical contaminated area



The contaminated zone has a 95% UCL of the mean of 200 mg/kg and a clean zone 95% UCL of the mean of 25 mg/kg.

The weighting process for this example is as follows:

1. The 95% UCL of the mean of the Contaminated Zone (200 mg/kg) is multiplied by its area (0.5 acres) and leads to a value of 100 mg acre/kg.
2. The 95% UCL of the mean of the Clean Zone (25 mg/kg) is multiplied by its area (1.5 acres) and leads to a value of 37.5 mg acre/kg.
3. The total of 1 and 2 above, 137.5 mg acre/kg, is divided by the functional area (which in this example is the same as the functional area) of 2 acres. This yields a weighted contaminant level for the site of 68.75 mg/kg.

4. This weighted contaminant level is compared against the inhalation pathway standard of 100 mg/kg and it is found that the inhalation pathway is not a concern for this particular situation.

Alternatively, the weighting process using this same example could be expressed as follows:

1. The extent of contamination is 25% of a 2 acre site (or alternatively functional area) and the 95% UCL of the mean of the contamination is 200 mg/kg. The weighted contaminant level is :

$$(0.25)(200 \text{ mg/kg}) = 50 \text{ mg/kg}$$

2. The remainder of the site (75%) is below the inhalation pathway standard and has a 95% UCL of the mean of 25 mg/kg. The weighted contaminant level is:

$$(0.75)(25 \text{ mg/kg}) = 18.75 \text{ mg/kg}$$

3. The weighted contaminant level for the total site is represented by the sum of the above two values which is 68.75 mg/kg.
4. Comparison of the weighted contaminant level for the functional area against the inhalation pathway standard of 100 mg/kg indicates that the inhalation pathway is not a concern for this particular situation.

To aid in the evaluation of potentially contaminated sites, a compliance protocol is provided in Appendix J.

VIII. References

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Appendices

Appendix A Inhalation Toxicity Factors

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
1	83-32-9	Acenaphthene (PAH)	1.1E-06	N&L TEF		
2	208-96-8	Acenaphthalene (PAH)	1.1E-06	N&L TEF		
3	61-64-1	Acetone			30881	ATSDR 03
4	98-86-2	Acetophenone			0.02	HEAST 92
5	107-02-8	Acrolein			0.02	IRIS
6	107-13-1	Acrylonitrile	6.8E-05	IRIS	2	IRIS
7	309-00-2	Aldrin	4.9E-03	IRIS		
8	7429-90-5	Aluminum (total)			3500	NCEA _{oral}
9	120-12-7	Anthracene (PAH)	1.1E-05	N&L TEF		
10	7440-36-0	Antimony (total)			0.2	IRIS
11	7440-38-2	Arsenic (total)	4.3E-03	IRIS	0.03	Cal 02a
12	1912-24-9	Atrazine			12	** IRIS _{oral}
13	7440-39-3	Barium (total)			0.5	HEAST 97
14	100-52-7	Benzaldehyde			350	IRIS _{oral}
15	71-43-2	Benzene	7.8E-06	IRIS	30	IRIS
16	92-87-5	Benzidine	6.7E-02	IRIS		
17	56-55-3	Benz(a)anthracene (PAH)	1.1E-04	Cal 02		
18	50-32-8	Benzo(a)pyrene (PAH)	1.1E-03	Cal 02		
19	205-99-2	Benzo(b)fluoranthene (PAH)	1.1E-04	Cal 02		
20	191-24-2	Benzo(g,h,i)perylene (PAH)	1.1E-05	N&L TEF		
21	207-08-9	Benzo(k)fluoranthene (PAH)	1.1E-04	Cal 02		
22	7440-41-7	Beryllium (total)	2.4E-03	IRIS	0.02	IRIS
23	92-52-4	1,1-Biphenyl			175	IRIS _{oral}
24	111-44-4	Bis(2-chloroethyl)ether	3.3E-04	IRIS		

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
25	39638-32-9	Bis(2-chloroisopropyl)ether	1.0E-05	HEAST 97		
26	117-81-7	Bis(2-ethylhexyl)phthalate	2.4E-06	Cal 02	10	Cal 97
27	75-27-4	Bromodichloromethane	3.7E-05	Cal 03		
28	75-25-2	Bromoform	1.1E-06	IRIS		
29	74-83-9	Bromomethane (Methyl bromide)			5	IRIS
30	78-93-3	2-Butanone (Methyl ethyl ketone)			1000	IRIS
31	85-68-7	Butylbenzyl phthalate			70	** IRIS _{oral}
32	7440-43-9	Cadmium (total)	4.2E-03	Cal 02	0.02	Cal 02a
33	105-60-2	Caprolactam			1750	IRIS _{oral}
34	86-74-8	Carbazole	5.7E-06	HEAST 97 _{oral}		
35	75-15-0	Carbon disulfide			700	IRIS
36	56-23-5	Carbon tetrachloride	1.5E-05	IRIS	40	Cal 02a
37	57-74-9	Chlordane (alpha + gamma)	1.0E-04	IRIS	0.7	IRIS
38	106-47-8	4-Chloroaniline			14	IRIS _{oral}
39	108-90-7	Chlorobenzene			1000	Cal 02a
40	75-00-3	Chloroethane (Ethyl chloride)			10000	IRIS
41	67-66-3	Chloroform	2.3E-05	IRIS	300	Cal 02a
42	74-87-3	Chloromethane (Methyl chloride)	1.8E-06	HEAST 97	90	IRIS
43	59-50-7	4-Chloro-3-methyl phenol *				
44	95-57-8	2-Chlorophenol			18	IRIS _{oral}
45	218-01-9	Chrysene (PAH)	1.1E-05	Cal 02		
46	7440-48-4	Cobalt (total)			0.005	Cal 97
47	7440-50-8	Copper (total)			0.02	Cal 97
48	57-12-5	Cyanide			70	IRIS _{oral}
49	72-54-8	4,4'-DDD (p,p'-TDE)	6.9E-05	Cal 03		
50	72-55-9	4,4'-DDE (p,p'-DDX)	9.7E-05	Cal 03		

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
51	50-29-3	4,4'DDT	9.7E-05	IRIS		
52	53-70-3	Dibenz(a,h)anthracene (PAH)	1.2E-03	Cal 02		
53	132-64-9	Dibenzofuran *				
54	124-48-1	Dibromochloromethane	2.7E-05	Cal 03		
55	96-12-8	1,2-Dibromo-3-chloropropane	2.0E-03	Cal 02	0.2	IRIS
56	106-93-4	1,2-Dibromoethane	2.2E-04	IRIS	0.8	Cal 02a
57	95-50-1	1,2-Dichlorobenzene (o-)			200	HEAST 97
58	541-73-1	1,3-Dichlorobenzene (m-)			301	A280 _{oral}
59	106-46-7	1,4-Dichlorobenzene (p-)	1.1E-05	Cal 02	80	IRIS/10
60	91-94-1	3,3'-Dichlorobenzidine	3.4E-04	Cal 02		
61	75-71-8	Dichlorodifluoromethane			200	HEAST 97
62	75-34-3	1,1-Dichloroethane	1.6E-06	Cal 02	500	HEAST 97
63	107-06-2	1,2-Dichloroethane	2.6E-05	IRIS	400	Cal 02a
64	75-35-4	1,1-Dichloroethene			20	IRIS/10
65	156-59-2	cis-1,2-Dichloroethylene			35	A280 _{oral}
66	156-60-5	trans-1,2-Dichloroethylene			60	A280 _{oral}
67	120-83-2	2,4-Dichlorophenol			11	IRIS _{oral}
68	78-87-5	1,2-Dichloropropane	1.0E-05	Cal 03	4	IRIS
69	542-75-6	1,3-Dichloropropene (cis and trans)	4.0E-06	IRIS	20	IRIS
70	60-57-1	Dieldrin	4.6E-03	IRIS		
71	84-66-2	Diethylphthalate			2800	IRIS _{oral}
72	105-67-9	2,4-Dimethyl phenol			70	IRIS _{oral}
73	131-11-3	Dimethyl phthalate *				
74	84-74-2	Di-n-butyl phthalate			350	IRIS _{oral}
75	534-52-1	4,6-Dinitro-2-methylphenol			0.4	NCEA _{oral}
76	51-28-5	2,4-Dinitrophenol			7	IRIS _{oral}

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
77	121-14-2	2,4-Dinitrotoluene	8.9E-05	Cal 02		
78	606-20-2	2,6-Dinitrotoluene	6.8E-01	IRIS _{oral}	4	HEAST 97 _{oral}
79	117-84-0	Di-n-octyl-phthalate	1.3E-07	USEPA 85		
80	122-66-7	1,2-Diphenylhydrazine	2.2E-04	IRIS		
81	115-29-7	Endosulfan I & II (a- & b-summed)			21	IRIS _{oral}
82	1031-07-8	Endosulfan sulfate			21	IRIS _{oral}
83	72-20-8	Endrin			1	IRIS _{oral}
84	100-41-4	Ethylbenzene			1000	IRIS
85	206-44-0	Fluoranthene (PAH)	1.1E-06	N&L TEF		
86	86-73-7	Fluorene (PAH)	1.1E-06	N&L TEF		
87	319-84-6	a-HCH (a-BHC)	1.8E-03	IRIS		
88	319-85-7	b-HCH (b-BHC)	5.3E-04	IRIS		
89	76-44-8	Heptachlor	1.3E-03	IRIS		
90	1024-57-3	Heptachlor epoxide	2.6E-03	IRIS		
91	118-74-1	Hexachlorobenzene	4.6E-04	IRIS		
92	87-68-3	Hexachloro-1,3-butadiene	2.2E-05	IRIS		
93	77-47-4	Hexachlorocyclopentadiene			0.2	IRIS
94	67-72-1	Hexachloroethane	4.0E-06	IRIS		
95	591-78-6	2-Hexanone			140	NCEA _{oral}
96	193-39-5	Indeno(1,2,3-cd)pyrene (PAH)	1.1E-04	Cal 02		
97	78-59-1	Isophorone			200	Cal 02b/10
98	7439-92-1	Lead (total)	1.2E-05	Cal 02	0.1	DEP/BAQEv 2002
99	58-89-9	Lindane (g-HCH) (g-BHC)	3.1E-04	Cal 02		
100	7439-96-5	Manganese (total)			0.05	IRIS
101	7439-97-6	Mercury (total)			0.3	IRIS

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
102	72-43-5	Methoxychlor			18	IRIS _{oral}
103	79-20-9	Methyl acetate			3500	HEAST 97 _{oral}
104	108-87-2	Methylcyclohexane			3000	HEAST 97
105	75-09-2	Methylene chloride	4.7E-07	IRIS	400	Cal 02a
116	108-10-1	4-Methyl-2-pentanone (MIBK)			3000	IRIS
117	95-48-7	2-Methylphenol (o-cresol)			60	Cal 02a/10
118	106-44-5	4-Methylphenol (p-cresol)			60	Cal 02a/10
119	1634-04-4	Methyl tert butyl ether (MTBE)	2.6E-07	Cal 02	300	IRIS/10
120	91-20-3	Naphthalene	1.1E-06	N&L TEF	0.3	IRIS/10
121	7440-02-0	Nickel (soluble salts)			0.2	TERA 99
122	88-74-4	2-Nitroaniline			0.2	HEAST 97
123	98-95-3	Nitrobenzene	1.2E-07	USEPA 85	2	HEAST 97; Cal 02b
124	100-02-7	4-Nitrophenol *				
125	62-75-9	N-Nitrosodimethylamine	1.4E-02	IRIS		
126	621-64-7	N-Nitrosodi-n-propylamine	2.0E-03	Cal 02		
127	86-30-6	N-Nitrosodiphenylamine	2.6E-06	Cal 02		
128	1336-36-3	PCBs (Polychlorinated biphenyls)	1.0E-04	IRIS		
129	87-86-5	Pentachlorophenol	5.1E-06	Cal 02		
130	85-01-8	Phenanthrene (PAH)	1.1E-06	N&L TEF		
131	108-95-2	Phenol			200	Cal 02a
132	129-00-0	Pyrene (PAH)	1.1E-06	N&L TEF		
133	7782-49-2	Selenium (total)			20	Cal 02a
134	7440-22-4	Silver (total)			18	IRIS _{oral}
135	100-42-5	Styrene	5.7E-07	HEAST 91	1000	IRIS
136	75-65-0	Tertiary butyl alcohol (TBA)			63	** DEP _{oral}
137	79-34-5	1,1,2,2-Tetrachloroethane	5.8E-05	IRIS		

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	/(ug/m ³)	Reference	ug/m ³	Reference
138	127-18-4	Tetrachloroethene (PCE)	5.9E-06	Cal 02	35	Cal 02a
139	7440-28-0	Thallium (total)			0.2	DEP/IRIS _{oral}
140	108-88-3	Toluene			400	IRIS
141	8001-35-2	Toxaphene	3.2E-04	IRIS		
142	120-82-1	1,2,4-Trichlorobenzene			200	HEAST 97
143	71-55-6	1,1,1-Trichloroethane			1000	Cal 02a
144	79-00-5	1,1,2-Trichloroethane	1.6E-05	IRIS		
145	79-01-6	Trichloroethene (TCE)	2.0E-06	Cal 02	600	Cal 02a
146	75-69-4	Trichlorofluoromethane			700	HEAST 97/Cal 02b
147	95-95-4	2,4,5-Trichlorophenol			350	IRIS _{oral}
148	88-06-2	2,4,6-Trichlorophenol	3.1E-06	IRIS		
149	76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane			30000	HEAST 97
150	7440-62-2	Vanadium (total)			25	HEAST 97 _{oral}
151	75-01-4	Vinyl chloride	8.8E-06	IRIS	100	IRIS
152	1330-20-7	Xylenes (total)			100	IRIS
153	7440-66-6	Zinc (total)			0.9	Cal 97

Comments

Values with references with an "oral" subscript are based on converted oral toxicity data in the absence of inhalation data.

Chemical names with a single asterisk (*) have no inhalation or oral toxicity values.

RfCs in italics are RfCs divided by 10, because they are Class C carcinogens (see Appendix B).

For C carcinogens with RfCs based on RfDs, the RfDs are already divided by 10. These compounds are noted by a double asterisk (**).

References

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Cal 97	California Environmental Protection Agency, Determination of Chronic Toxicity Reference Exposure Levels (Draft), October 1998.
Cal 02	California Environmental Protection Agency, Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II – Technical Support Document for Describing Available Cancer Potency Factors, December 2002.
Cal 02a	California Office of Environmental Health Hazard Assessment (OEHHA), "All Chronic Reference Exposure Levels Adopted by OEHHA as of September 2002" (www.oehha.ca.gov/air/chronic_rels/AllChrels.html).
Cal 02b	California Air Resources Board (ARB), "Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values," updated 11/7/02; (www.arb.ca.gov/toxics/healthval/healthval.htm)
Cal 03	Cal/EPA Toxicity Criteria Database (www.oehha.ca.gov/risk/ChemicalDB/index.asp), updated 1/30/2003.
DEP/BAQ Ev 2002	NJDEP Air Quality Permitting Program, Bureau of Air Quality Evaluation, "Development of a Reference Concentration for Lead," 5/28/2002.
HEAST 91	U.S. Environmental Protection Agency (USEPA), Health Effects Assessment Summary Tables, Annual FY-1991, Jan. 1991.
HEAST 92	USEPA Health Effects Assessment Summary Tables, Annual Update 1992, March 1992.
HEAST 97	USEPA, Health Effects Assessment Summary Tables, FY-1997 Update, July 1997.
IRIS	USEPA, Integrated Risk Information System, current; www.epa.gov/iris ; current.
N&L TEF	Nisbet, I.C.T, and P.K. LaGoy, 1992, Toxic equivalency factors for polycyclic aromatic hydrocarbons, Reg. Toxicol. Pharmacol. 16:290-300. See Table 4, page 296.

NCEA	USEPA National Center for Environmental Assessment.
TERA 99	Toxicology Excellence for Risk Assessment, Toxicological Review of Soluble Nickel Salts, March 1999.
USEPA 85	USEPA, The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants, Office of Air and Radiation, Washington, D.C., 1985, EPA-450/1-85-001. See Attachment A, Summary Table.

Chemicals Using Converted Oral Toxicity Data in the Absence of Inhalation Toxicity Data

1	7429-90-5	Aluminum (total)
2	1912-24-9	Atrazine
3	100-52-7	Benzaldehyde
4	92-52-4	1,1-Biphenyl
5	85-68-7	Butylbenzyl phthalate
6	105-60-2	Caprolactam
7	86-74-8	Carbazole
8	106-47-8	4-Chloroaniline
9	95-57-8	2-Chlorophenol
10	57-12-5	Cyanide
11	541-73-1	1,3-Dichlorobenzene (m-)
12	156-59-2	cis-1,2-Dichloroethene
13	156-60-5	trans-1,2-Dichloroethene
14	120-83-2	2,4-Dichlorophenol
15	84-66-2	Diethylphthalate
16	105-67-9	2,4-Dimethyl phenol
17	84-74-2	Di-n-butyl phthalate
18	534-52-1	4,6-Dinitro-2-methylphenol
19	51-28-5	2,4-Dinitrophenol
20	606-20-2	2,6-Dinitrotoluene
21	115-29-7	Endosulfan I & II (a- & b- summed)
22	1031-07-8	Endosulfan sulfate
23	72-20-8	Endrin
24	591-78-6	2-Hexanone
25	72-43-5	Methoxychlor
26	79-20-9	Methyl acetate
27	7440-22-4	Silver (total)
28	75-65-0	Tertiary butyl alcohol (TBA)

29	7440-28-0	Thallium (total)
30	95-95-4	2,4,5-Trichlorophenol
32	7440-62-2	Vanadium (total)

The following equations were used to convert oral toxicity data to inhalation values.

Conversion of Reference Dose to Reference Concentration

$$RfC = RfD * \frac{1}{IR} * BW * 1000 \frac{\mu g}{mg}$$

Where:

RfC = reference concentration in $\mu g/m^3$

RfD = reference dose in mg/kg/day

IR = inhalation rate of 20 m^3/day

BW = body weight of 70 kg

Conversion of Cancer Slope Factor (CSF) to Unit Risk Factor (URF) in $(\mu g/m^3)^{-1}$:

$$URF = CSF * \frac{1}{BW} * IR * \frac{1 \text{ mg}}{1000 \mu g}$$

Where:

URF = unit risk factor in $(\mu g/m^3)^{-1}$

CSF = cancer slope factor in $(mg/kg-day)^{-1}$

BW = body weight of 70 kg

IR = inhalation rate of 20 m^3/day

Appendix B Inhalation Class C Carcinogen Compounds

Atrazine

Butylbenzyl phthalate

Dibromochloromethane

1,4 Dichlorobenzene

1,1 Dichloroethene

b- HCH

Hexachloro-1,3-butadiene

Hexachloroethane

Isophorone

2 Methylphenol

4 Methylphenol

Methyl tertiary butyl ether (MTBE)

Napthalene

Tertiary butyl alcohol (TBA)

1,1,2,2 Tetrachloroethane

1,1,2 Trichloroethane

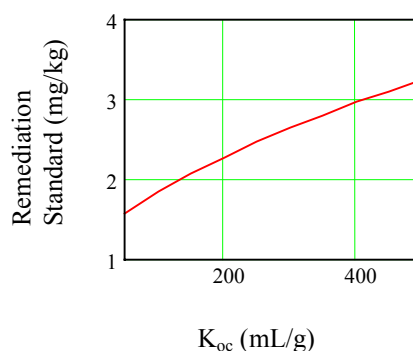
Appendix C Sensitivity Analysis – Volatile Organic Compounds

For this analysis, only one variable was modified at a time, with the other chemical and environmental values being held at their generic New Jersey values. Soil and chemical properties were varied within their normal ranges. Results below are shown for benzene, but observed sensitivities are similar for all volatile organic compounds.

1. Sensitivity of the remediation standard to the organic carbon partition coefficient (K_{oc}).

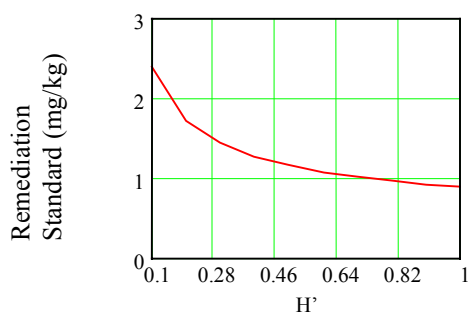
Sensitivity to this parameter is small, due to the weak adsorption of all these chemicals to soil. A ten-fold variation in the K_{oc} value affected the calculated standard by less than a factor of two.

K _{oc} (cm ³ /g)	Remediation Std. (mg/kg)
50	1.568
100	1.847
150	2.075
200	2.281
250	2.469
300	2.645
350	2.809
400	2.964
450	3.111
500	3.252



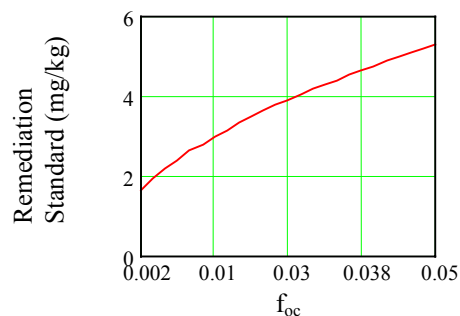
2. Sensitivity of the remediation standard to the Henry's law constant (H'). Dimensionless Henry's law constants for volatile organic chemicals are usually in the range of 0.1 to 1. This variation in the value of H' has a relatively small effect on the calculated remediation standard, which varied by a little more than a factor of two.

H'	Remediation Std. (mg/kg)
0.1	2.403
0.2	1.736
0.3	1.446
0.4	1.277
0.5	1.163
0.6	1.081
0.7	1.018
0.8	0.969
0.9	0.928
1	0.894



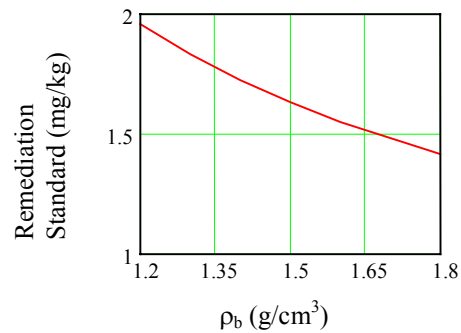
3. Sensitivity of the remediation standard to soil organic carbon (f_{oc}). The fraction of organic carbon in soils generally range from about 0.002 to 0.05. This variation in organic carbon has a relatively small effect on calculated remediation standards, which varied by a factor of three.

f_{oc}	Remediation Std. (mg/kg)
0.002	1.635
0.006	2.187
0.01	2.626
0.014	3.001
0.018	3.334
0.022	3.637
0.026	3.916
0.03	4.177
0.034	4.423
0.038	4.655
0.042	4.877
0.046	5.088
0.05	5.292



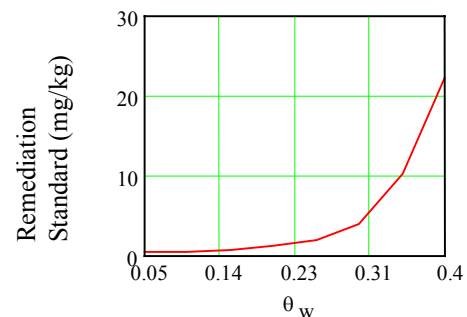
4. Sensitivity of remediation standard to soil bulk density (ρ_b). Soil bulk densities vary over a relatively narrow range, from about 1.2 to 1.8. This causes only small variations in the calculated remediation standard.

ρ_b (g/cm ³)	Remediation Std. (mg/kg)
1.2	1.962
1.3	1.837
1.4	1.729
1.5	1.635
1.6	1.553
1.7	1.48
1.8	1.415



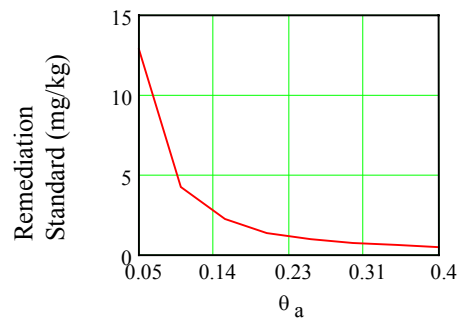
5. Sensitivity of remediation standard to soil moisture (θ_w). Soil moisture has a substantial effect on calculated remediation standards. This parameter may range from about 0.05 (v/v) to saturation volume (about 0.4 (v/v)). At higher moisture levels, small changes result in significant increases in the remediation standard. This is due to the exponential behavior of the model with respect to soil moisture. However, average soil moisture contents are less than saturation levels, and not on the most sensitive portion of the curve.

θ_w	Remediation Std. (mg/kg)
0.05	0.428
0.1	0.582
0.15	0.823
0.2	1.232
0.25	2.023
0.3	3.909
0.35	10.35
0.4	22.143



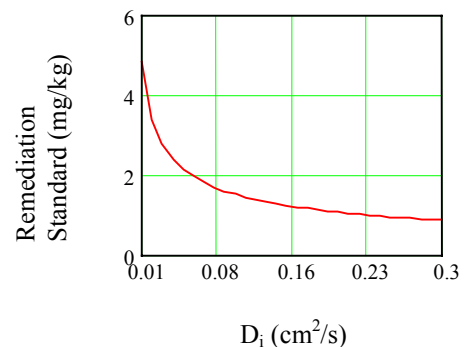
6. Sensitivity of remediation standard to soil air content (θ_a). This parameter is inversely related to soil moisture, and shows a similar, but inverted sensitivity behavior. At low soil air content levels (corresponding to high soil moisture contents), small changes in this parameter have a large effect on the remediation standard. However, average soil air contents are generally in the midrange of the curve, where the sensitivity is lower.

θ_a	Remediation Std. (mg/kg)
0.05	12.871
0.1	4.252
0.15	2.198
0.2	1.379
0.25	0.963
0.3	0.719
0.35	0.563
0.4	0.456



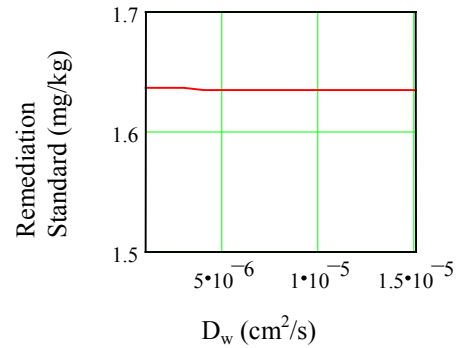
7. Sensitivity of remediation standard to diffusion coefficient in air, (D_i). The remediation standard is inversely related to D_i , but the sensitivity is relatively low. For most volatiles, D_i varies from about 0.07 to 0.1 cm^2/sec , and this range has little effect on the calculated standard.

$D_i (\text{cm}^2/\text{s})$	Remediation Std. (mg/kg)
0.01	4.83
0.05	2.169
0.1	1.534
0.15	1.253
0.2	1.085
0.25	0.971
0.3	0.886



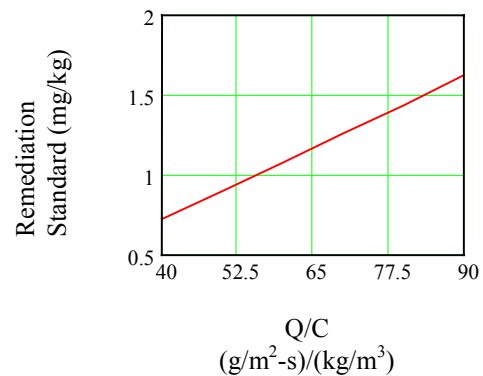
8. Sensitivity of remediation standard to the diffusion coefficient in water, (D_w). The normal range of this parameter for volatiles is $1\text{E-}5$ to $1\text{E-}6$ cm^2/sec . It has virtually no effect on the calculated remediation standard.

D_w (cm^2/s)	Remediation Std. (mg/kg)
0.000001	1.636
0.000004	1.636
0.000008	1.635
0.000012	1.635
0.000015	1.635



9. Sensitivity of remediation standard to Q/C . The Q/C value determines the dispersion and dilution of contaminant as it leaves the soil surface and enters the atmosphere. The remediation standard is linearly related to the value of this parameter.

Q/C ($(\text{g}/\text{m}^2\text{-s})/(\text{kg}/\text{m}^3)$)	Remediation Std. (mg/kg)
40	0.72
50	0.9
60	1.081
70	1.261
80	1.441
90	1.621



Appendix D Generic Soil Moisture Content -Volatile Organic Compounds

The soil moisture has a large effect on the generic inhalation remediation standards for volatiles. An average annual soil moisture of 0.23 (v/v) was calculated for New Jersey sandy loam soil using a simple relationship described in the USEPA Soil Screening Level User's Guide (USEPA 1996a):

$$\theta_w = n(I / K_s)^{1/(2b+3)} \quad \text{Equation 1}$$

where n is the total soil porosity, I is the soil moisture infiltration rate (m/yr), K_s is the saturated hydraulic conductivity of the soil (m/yr), and the factor $1/(2b+3)$ is determined by the soil type and is provided in a lookup table in the User's Guide. Rather than estimating soil porosity as described in the User's Guide it was preferred to use a value of 0.41 for sandy loam soil that was statistically derived from the extensive soil database of Carsel and Parrish (1988). This reference is one of EPA's data sources for soil properties for the USEPA SSL document. Additionally, a K_s value of 387 m/yr for sandy loam soil (from Carsel and Parrish, 1988) was used instead of the lookup value of 230 m/yr provided in the user's guide because it is a more recent evaluation.

The final parameter for Equation 1 above is the infiltration rate, I . Infiltration rates for New Jersey soils were determined using a New Jersey-specific tool available from the New Jersey Geological Survey. The New Jersey Geological Survey has published a method for determining infiltration rates for New Jersey as a function of location, soil type and land use (Hoffman, 1999; Charles et al., 1996). Using several of the most commonly occurring soils in New Jersey (Tedrow, 1986), infiltration rates were calculated for each soil in each county where the soil had a significant presence (Table 1). For each calculation, data from a climate station from a municipality located in the area where the soil would occur was used. Three land uses were selected for each calculation: landscaped, bare soil, and agricultural soil. All three of these soil types assume 100% of the surface area is permeable. All sandy loam soils with significant acreage in the state (as mapped by Tedrow, 1986) were used, since this soil texture has been

targeted as the default soil texture for New Jersey generic standards (see main body of this document). In addition, other soil textures with a large presence in the state (as mapped by Tedrow, 1986) were also studied, in order to determine the overall variation of infiltration rates in the state, and to verify that sandy loam soil was appropriate as a default soil texture. A limitation of this method is that the infiltration calculated (below the root zone) is assumed to be equal to groundwater recharge (Charles et al., 1996).

Table 1. Recharge rates for various soils, locations and land uses in New Jersey

Soil Name	Primary Counties of Occurrence	Representative Municipality	Recharge (in/yr)		
			Landsaped Open Space	Unvegetated	General Agriculture
Sassafras sandy loam	Mercer	Washington Twp.	13.2	8.8	11.6
Sassafras sandy loam	Middlesex	South River Boro	14.2	9.3	12.5
Sassafras sandy loam	Burlington	Delran Twp.	12.8	8.5	11.3
Sassafras sandy loam	Salem	Alloway Twp.	11.6	7.9	10.2
Sassafras sandy loam	Cumberland	Bridgeton City	11	7.6	9.7
Freehold sandy loam	Monmouth	Millstone Twp.	13.1	8.6	11.5
Freehold sandy loam	Burlington	Chesterfield Twp.	13.1	8.6	11.5
Freehold sandy loam	Camden	Runnemede Boro	11.7	7.8	10.2
Freehold sandy loam	Gloucester	Swedesboro Boro	11.5	7.7	10.1
Collington sandy loam	Monmouth	Holmdel Twp.	13.4	8.5	11.7
Colts Neck sandy loam	Monmouth	Colts Neck Twp.	13.2	8.7	11.9
Westphalia sandy loam	Camden	Lindenwold Boro	11.6	7.3	10.1
Westphalia sandy loam	Gloucester	Harrison Twp.	11.4	7.3	9.9
Aura sandy loam	Gloucester	Elk Twp.	11.9	8.1	10.5
Aura sandy loam	Salem	Pittsgrove Twp.	11.7	8	10.4
Aura sandy loam	Cumberland	Upper Deerfield Twp.	11.5	7.9	10.2
Dunnellen sandy loam	Bergen	Oradell Boro	16.4	10.3	14.4
Dunnellen sandy loam	Union	Plainfield City	15.6	9.9	13.8
Dunnellen sandy loam	Middlesex	Piscataway Twp.	15.1	9.7	13.3
Galestown sand	Mercer	Trenton City	15.1	13	14.3
Galestown sand	Burlington	Burlington City	14.9	12.8	14.1
Lakewood sand	Monmouth	Neptune Twp.	17.5	14.7	16.6
Lakewood sand	Ocean	Manchester Twp.	17.2	14.4	16.3
Lakewood sand	Burlington	Pemberton Twp.	15.5	13.3	14.7
Downer loamy sand	Monmouth	Neptune Twp.	16.2	10.8	14.6
Downer loamy sand	Ocean	Manchester Twp.	15.9	10.6	14.2
Downer loamy sand	Burlington	Pemberton Twp.	14.4	9.7	12.9
Downer loamy sand	Atlantic	Galloway Twp.	11.5	7.9	10.2
Downer loamy sand	Cumberland	Vineland City	12.3	8.5	11
Hammonton loamy sand	Atlantic	Estelle Manor City	12.1	8.5	10.7
Hammonton loamy sand	Cumberland	Hopewell Twp.	12.1	8.5	10.7
Hammonton loamy sand	Cape May	Lower Twp.	10.2	7.4	8.9
Boonton loam	Passaic	Hawthorne Boro	13.9	6.4	11.6
Boonton loam	Hudson	Harrison Town	10.1	4.7	8.5
Boonton loam	Essex	Newark City	10.1	4.7	8.5
Boonton loam	Union	Roselle Park	10.1	4.7	8.5
Boonton loam	Middlesex	Perth Amboy City	13.1	6	10.9
Boonton loam	Bergen	Ramsey Boro	13.9	6.4	11.6
Rockaway loam	Passaic	Ringwood Boro	17.2	8.6	14.6
Rockaway loam	Morris	Rockaway Twp.	16.5	8.3	14
Rockaway loam	Sussex	Franklin Boro	15.2	7.7	13
Annandale loam	Morris	Chester Twp.	16.9	8.4	13.9
Annandale loam	Warren	Pohatcong Twp.	12.4	6.7	10.2
Annandale loam	Hunterdon	Tewksbury Twp.	16.3	8.2	13.5
Penn silt loam	Somerset	Hillsborough Twp.	12.6	5.6	10.5
Penn silt loam	Hunterdon	Delaware Twp.	12	5.3	10

Table 2

Summary of infiltration rates of New Jersey Soils

<i>Soil Texture</i>	<i>Average infiltration rates (in./yr)</i>			<i>Overall</i>
	<i>Landscaped</i>	<i>Unvegetated</i>	<i>Agriculture</i>	
Sandy loam	12.8	8.4	11.3	10.9
Sand	16	13.6	15.2	15
Loamy sand	13.1	9	11.6	11.2
Loam	13.8	6.7	11.6	10.7
Silt loam	12.3	5.4	10.2	9.3
All soils	13.5	8.5	11.8	11.3

Table 2 indicates that an 11"/yr (0.28 m/yr) infiltration is representative, on average, for sandy loam, loamy sand, and loam soils. Silt loam soils have slightly lower infiltration rates, while sand soils yield rates a few inches higher. As discussed in the main body of the text of this document, it was decided to use sandy loam soil texture as the generic soil type for New Jersey, as it was felt that use of a sand soil would be overly protective for much of the state. The results above confirm that assuming an infiltration rate of 11"/yr (0.28 m/yr) is adequately protective for sandy loam soil and most other soil textures.

Using Equation 1 and all input parameters discussed above, the average soil moisture for sandy loam was determined to be 0.23 (v/v).

References

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- Hoffman, J.L. (1999). DGS 99-2: Microsoft Excel Workbook Implementing the New Jersey Geological Survey's Ground-Water Recharge Methodology. New Jersey Geological Survey, New Jersey Dept. of Environmental Protection: Trenton, New Jersey.
- Tedrow, J.F. (1986). *Soils of New Jersey*. R.E.Krieger: Malabar, FL.

United States Environmental Protection Agency (USEPA) 1996a. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-95/128.

Appendix E Chemical Properties

CHEMICAL	CAS No.	Soil organic carbon-water partition coefficient, K_{oc} (mL/g)	Henry's law constant, H' (dimensionless)	Diffusion coefficient in air, D_1 (cm ² /s)	Diffusion coefficient in water, D_w (cm ² /s)	Water Solubility, S (mg/L)
Acenaphthene (PAH)	83-32-9	7.08E+03	6.36E-03	4.21E-02	7.69E-06	4.24E+00
Acenaphthalene (PAH)	208-96-8	2.76E+03	4.51E-03	4.40E-02	7.50E-06	1.60E+01
Acetone	67-64-1	5.75E-01	1.59E-03	1.24E-01	1.14E-05	1.00E+06
Acetophenone	98-86-2	3.70E+01	4.51E-04	6.00E-02	8.70E-06	6.10E+03
Acrolein	107-02-8	1.00E+00	4.92E-03	1.05E-01	1.20E-05	2.10E+05
Acrylonitrile	107-13-1	2.00E+00	4.10E-03	1.22E-01	1.30E-05	7.40E+04
Aldrin	309-00-2	2.45E+06	6.97E-03	1.32E-02	4.86E-06	1.80E-01
Anthracene (PAH)	120-12-7	2.95E+04	2.67E-03	3.24E-02	7.74E-06	4.34E-02
Atrazine	1912-24-9	3.60E+02	1.21E-07	2.60E-02	6.70E-06	7.00E+01
Benzaldehyde	100-52-7	2.90E+01	1.09E-03	7.30E-02	9.10E-06	3.00E+03
Benzene	71-43-2	5.89E+01	2.28E-01	8.80E-02	9.80E-06	1.75E+03
Benzidine	92-87-5	4.70E+01	1.60E-09	3.40E-02	1.50E-05	5.00E+02
Benz(a)anthracene (PAH)	56-55-3	3.98E+05	1.37E-04	5.10E-02	9.00E-06	9.40E-03
Benzo(a)pyrene (PAH)	50-32-8	1.02E+06	4.63E-05	4.30E-02	9.00E-06	1.62E-03
Benzo(b)fluoranthene (PAH)	205-99-2	1.23E+06	4.55E-03	2.26E-02	5.56E-06	1.50E-03
Benzo(g,h,i)perylene (PAH)	191-24-2	3.86E+06	5.74E-06	2.01E-02	5.30E-06	2.60E-04
Benzo(k)fluoranthene (PAH)	207-08-9	1.23E+06	3.40E-05	2.26E-02	5.56E-06	8.00E-04
1,1-Biphenyl	92-52-4	8.56E+03	1.23E-02	4.04E-02	8.20E-06	6.00E+00
Bis(2-chloroethyl)ether	111-44-4	1.55E+01	7.38E-04	6.92E-02	7.53E-06	1.72E+04
Bis(2-chloroisopropyl)ether	39638-32-9	3.60E+02	3.03E-03	6.02E-02	6.40E-06	1.30E+03
Bis(2-ethylhexyl)phthalate	117-81-7	1.51E+07	4.18E-06	3.51E-02	3.66E-06	3.40E-01
Bromodichloromethane	75-27-4	5.50E+01	6.56E-02	2.98E-02	1.06E-05	6.74E+03
Bromoform	75-25-2	8.71E+01	2.19E-02	1.49E-02	1.03E-05	3.10E+03
Bromomethane (Methyl bromide)	74-83-9	1.05E+01	2.56E-01	7.28E-02	1.21E-05	1.52E+04
2-Butanone (Methyl ethyl ketone)	78-93-3	1.00E+00	2.30E-03	8.08E-02	9.80E-06	2.20E+05
Butyl benzyl phthalate	85-68-7	5.75E+04	5.17E-05	1.74E-02	4.83E-06	2.69E+00
Caprolactam	105-60-2	6.00E+00	1.50E-07	6.50E-02	9.00E-06	3.01E+05
Carbazole	86-74-8	3.39E+03	6.26E-07	3.90E-02	7.03E-06	7.48E+00
Carbon disulfide	75-15-0	4.57E+01	1.24E+00	1.04E-01	1.00E-05	1.19E+03
Carbon tetrachloride	56-23-5	1.74E+02	1.25E+00	7.80E-02	8.80E-06	7.93E+02
Chlordane (alpha + gamma)	57-74-9	1.20E+05	1.99E-03	1.18E-02	4.37E-06	5.60E-02
4-Chloroaniline	106-47-8	6.61E+01	1.36E-05	4.83E-02	1.01E-05	5.30E+03
Chlorobenzene	108-90-7	2.19E+02	1.52E-01	7.30E-02	8.70E-06	4.72E+02
Chloroethane (Ethyl chloride)	75-00-3	1.50E+01	3.61E-01	2.71E-01	1.10E-05	5.70E+03
Chloroform	67-66-3	3.98E+01	1.50E-01	1.04E-01	1.00E-05	7.90E+03
Chloromethane (Methyl chloride)	74-87-3	6.00E+00	3.61E-01	1.26E-01	6.50E-06	5.30E+03
4-Chloro-3-methyl phenol	59-50-7	1.12E+03	1.64E-05	4.20E-02	9.50E-06	3.80E+03
2-Chlorophenol	95-57-8	3.88E+02	1.60E-02	5.01E-02	9.46E-06	2.20E+04
Chrysene (PAH)	218-01-9	3.98E+05	3.88E-03	2.48E-02	6.21E-06	1.60E-03
DDD	72-54-8	1.00E+06	1.64E-04	1.69E-02	4.76E-06	9.00E-02
DDE	72-55-9	4.47E+06	8.61E-04	1.44E-02	5.87E-06	1.20E-01
DDT	50-29-3	2.63E+06	3.32E-04	1.37E-02	4.95E-06	2.50E-02
Dibenz(a,h)anthracene (PAH)	53-70-3	3.80E+06	6.03E-07	2.02E-02	5.18E-06	2.49E-03
Dibenzofuran	132-64-9	1.35E+04	5.33E-04	2.67E-02	6.00E-06	1.00E+01
Dibromochloromethane	124-48-1	6.31E+01	3.21E-02	1.96E-02	1.05E-05	2.60E+03
1,2-Dibromo-3-chloropropane	96-12-8	7.90E+01	6.15E-03	2.12E-02	7.00E-06	1.20E+03
1,2-Dibromoethane	106-93-4	4.60E+01	3.03E-02	2.87E-02	8.10E-06	4.20E+03
1,2-Dichlorobenzene (o-)	95-50-1	6.17E+02	7.79E-02	6.90E-02	7.90E-06	1.56E+02
1,3-Dichlorobenzene (m-)	541-73-1	7.08E+02	1.27E-01	6.92E-02	7.90E-06	1.30E+02
1,4-Dichlorobenzene (p-)	106-46-7	6.17E+02	9.96E-02	6.90E-02	7.90E-06	7.38E+01
3,3'-Dichlorobenzidine	91-94-1	7.24E+02	1.64E-07	1.94E-02	6.74E-06	3.11E+00

CHEMICAL	CAS No.	Soil organic carbon-water partition coefficient, K _{oc} (mL/g)	Henry's law constant, H [†] (dimensionless)	Diffusion coefficient in air, D _i (cm ² /s)	Diffusion coefficient in water, D _w (cm ² /s)	Water Solubility, S (mg/L)
Dichlorodifluoromethane	75-71-8	6.60E+01	1.39E+01	5.20E-02	1.00E-05	2.80E+02
1,1-Dichloroethane	75-34-3	3.16E+01	2.30E-01	7.42E-02	1.05E-05	5.06E+03
1,2-Dichloroethane	107-06-2	1.74E+01	4.01E-02	1.04E-01	9.90E-06	8.52E+03
1,1-Dichloroethylene	75-35-4	5.89E+01	1.07E+00	9.00E-02	1.04E-05	2.25E+03
cis-1,2-Dichloroethene	156-59-2	3.55E+01	1.67E-01	7.36E-02	1.13E-05	3.50E+03
trans-1,2-Dichloroethene	156-60-5	5.25E+01	3.85E-01	7.07E-02	1.19E-05	6.30E+03
2,4-Dichlorophenol	120-83-2	1.47E+02	1.30E-04	3.46E-02	8.77E-06	4.50E+03
1,2-Dichloropropane	78-87-5	4.37E+01	1.15E-01	7.80E-02	8.73E-06	2.80E+03
1,3-Dichloropropene	542-75-6	4.57E+01	7.26E-01	6.26E-02	1.00E-05	2.80E+03
Dieldrin	60-57-1	2.14E+04	6.19E-04	1.25E-02	4.74E-06	1.95E-01
Diethylphthalate	84-66-2	2.88E+02	1.85E-05	2.56E-02	6.35E-06	1.08E+03
2,4-Dimethylphenol	105-67-9	2.09E+02	8.20E-05	5.84E-02	8.69E-06	7.87E+03
Dimethyl phthalate	131-11-3	3.70E+01	4.51E-06	5.68E-02	6.30E-06	4.00E+03
Di-n-butyl phthalate	84-74-2	3.39E+04	3.85E-08	4.38E-02	7.86E-06	1.12E+01
4,6-Dinitro-2-methylphenol	534-52-1	1.16E+02	1.76E-05	2.93E-02	6.90E-06	2.00E+02
2,4-Dinitrophenol	51-28-5	1.00E-02	1.82E-05	2.73E-02	9.06E-06	2.79E+03
2,4-Dinitrotoluene	121-14-2	9.55E+01	3.80E-06	2.03E-01	7.06E-06	2.70E+02
2,6-Dinitrotoluene	606-20-2	6.92E+01	3.06E-05	3.27E-02	7.26E-06	1.82E+02
Di-n-octyl-phthalate	117-84-0	8.32E+07	2.74E-03	1.51E-02	3.58E-06	2.00E-02
Dioxin (2,3,7,8-TCDD)	1746-01-6	2.45E+06	3.24E-03	1.04E-01	5.60E-06	7.90E-06
1,2-Diphenylhydrazine	122-66-7	7.10E+02	6.15E-05	3.17E-02	7.40E-06	6.80E+01
Endosulfan I & II (a- & b-, summed)	115-29-7	2.14E+03	4.59E-04	1.15E-02	4.55E-06	5.10E-01
Endosulfan sulfate	1031-07-8	1.02E+03	8.61E-02	1.10E-02	4.40E-06	6.40E+00
Endrin	72-20-8	1.23E+04	3.08E-04	1.25E-02	4.74E-06	2.50E-01
Ethylbenzene	100-41-4	3.63E+02	3.23E-01	7.50E-02	7.80E-06	1.69E+02
Fluoranthene (PAH)	206-44-0	1.07E+05	6.60E-04	3.02E-02	6.35E-06	2.06E-01
Fluorene (PAH)	86-73-7	1.38E+04	2.61E-03	3.63E-02	7.88E-06	1.98E+00
a-HCH	319-84-6	1.23E+03	4.35E-04	1.42E-02	7.34E-06	2.00E+00
b-HCH	319-85-7	1.26E+03	3.05E-05	1.42E-02	7.34E-06	2.40E-01
Heptachlor	76-44-8	1.41E+06	6.07E+01	1.12E-02	5.69E-06	1.80E-01
Heptachlor epoxide	1024-57-3	8.32E+04	3.90E-04	1.32E-02	4.23E-06	2.00E-01
Hexachlorobenzene	118-74-1	5.50E+04	5.41E-02	5.42E-02	5.91E-06	6.20E+00
Hexachloro-1,3-butadiene	87-68-3	5.37E+04	3.34E-01	5.61E-02	6.16E-06	3.23E+00
Hexachlorocyclopentadiene	77-47-4	2.00E+05	1.11E+00	1.61E-02	7.21E-06	1.80E+00
Hexachloroethane	67-72-1	1.78E+03	1.59E-01	2.50E-03	6.80E-06	5.00E+01
2-Hexanone	591-78-6	2.40E+01	3.80E-03			1.80E+04
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	3.47E+06	6.56E-05	1.90E-02	5.66E-06	2.20E-05
Isophorone	78-59-1	4.68E+01	2.72E-04	6.23E-02	6.76E-06	1.20E+04
Lindane (g-HCH)	58-89-9	1.07E+03	5.74E-04	1.42E-02	7.34E-06	6.80E+00
Mercury	7439-97-6	---	4.67E-01	3.07E-02	6.30E-06	---
Methoxychlor	72-43-5	9.77E+04	6.48E-04	1.56E-02	4.46E-06	4.50E-02
Methyl acetate	79-20-9	2.00E+00	2.10E-02	1.04E-01	1.00E-05	2.40E+05
Methylcyclohexane	108-87-2	8.65E+02	1.76E+01	9.86E-02	8.50E-06	1.40E+01
Methylene chloride	75-09-2	1.17E+01	8.98E-02	1.01E-01	1.17E-05	1.30E+04
4-Methyl-2-pentanone (MIBK)	108-10-1	1.50E+01	5.74E-03	7.50E-02	7.80E-06	1.90E+04
2-Methylphenol (o-cresol)	95-48-7	9.12E+01	4.92E-05	7.40E-02	8.30E-06	#REF!
4-Methylphenol (p-cresol)	106-44-5	7.40E+01	3.24E-05	7.40E-02	1.00E-05	2.20E+04
Methyl tert butyl ether (MTBE)	1634-04-4	8.00E+00	2.40E-02	1.02E-01	1.00E-05	4.80E+04
Naphthalene	91-20-3	2.00E+03	1.98E-02	5.90E-02	7.50E-06	3.10E+01
o-Nitroaniline (2-)	88-74-4	7.40E+01	7.42E-07	7.30E-02	8.00E-06	2.90E+02
Nitrobenzene	98-95-3	6.46E+01	9.84E-04	7.60E-02	8.60E-06	2.09E+03
4-Nitrophenol	100-02-7	7.40E+01	1.72E-08	4.30E-02	9.60E-06	1.20E+04
N-Nitrosodimethylamine	62-75-9	3.00E-01	4.92E-05	1.13E-01	1.20E-05	1.00E+06
N-Nitrosodi-n-propylamine	621-64-7	2.40E+01	9.23E-05	5.45E-02	8.17E-06	9.89E+03
N-Nitrosodiphenylamine	86-30-6	1.29E+03	2.05E-04	3.12E-02	6.35E-06	3.51E+01

CHEMICAL	CAS No.	Soil organic carbon-water partition coefficient, K _{oc} (mL/g)	Henry's law constant, H' (dimensionless)	Diffusion coefficient in air, D _i (cm ² /s)	Diffusion coefficient in water, D _w (cm ² /s)	Water Solubility, S (mg/L)
PCBs (Polychlorinated biphenyls)	1336-36-3	3.09E+05	1.07E-01	1.75E-02	8.00E-06	7.00E-01
Pentachlorophenol	87-86-5	5.92E+02	1.00E-06	5.60E-02	6.10E-06	1.95E+03
Phenanthrene (PAH)	85-01-8	2.65E+04	9.43E-04	3.33E-02	7.50E-06	1.10E+00
Phenol	108-95-2	2.88E+01	1.63E-05	8.20E-02	9.10E-06	8.28E+04
Pyrene (PAH)	129-00-0	1.05E+05	4.51E-04	2.72E-02	7.24E-06	1.35E-01
Styrene	100-42-5	7.76E+02	1.13E-01	7.10E-02	8.00E-06	3.10E+02
Tertiary butyl alcohol (TBA)	75-65-0	2.00E+00	4.82E-04			
1,1,2,2-Tetrachloroethane	79-34-5	9.33E+01	1.41E-02	7.10E-02	7.90E-06	2.97E+03
Tetrachloroethene	127-18-4	1.55E+02	7.54E-01	7.20E-02	8.20E-06	2.00E+02
Toluene	108-88-3	1.82E+02	2.72E-01	8.70E-02	8.60E-06	5.26E+02
Toxaphene	8001-35-2	2.57E+05	2.46E-04	1.16E-02	4.34E-06	7.40E-01
1,2,4-Trichlorobenzene	120-82-1	1.78E+03	5.82E-02	3.00E-02	8.23E-06	3.00E+02
1,1,1-Trichloroethane	71-55-6	1.10E+02	7.05E-01	7.80E-02	8.80E-06	1.33E+03
1,1,2-Trichloroethane	79-00-5	5.01E+01	3.74E-02	7.80E-02	8.80E-06	4.42E+03
Trichloroethylene	79-01-6	1.66E+02	4.22E-01	7.90E-02	9.10E-06	1.10E+03
Trichlorofluoromethane	75-69-4	1.14E+02	3.98E+00	4.26E-02	1.00E-05	1.10E+03
2,4,5-Trichlorophenol	95-95-4	1.60E+03	1.78E-04	2.91E-02	7.03E-06	1.20E+03
2,4,6-Trichlorophenol	88-06-2	3.81E+02	3.19E-04	3.18E-02	6.25E-06	8.00E+02
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	4.10E+02	1.97E+01	7.80E-02	8.20E-06	1.70E+02
Vinyl chloride	75-01-4	1.86E+01	1.11E+00	1.06E-01	1.23E-06	2.76E+03
Xylenes (total)	1330-20-7	3.89E+02	3.14E-01	7.69E-02	8.44E-06	1.85E+02
Sources for chemical properties:						
K _{oc} values: Primary source is Table 39 or 42 (pH 6.8 from (1). For underlined values see (6); for italicized values see (7).						
H' values: Primary source is Table 36 from (1). For underlined values see (2); for italicized values see (4).						
D _i values: Primary source is Table 37 from (1). For underlined values see (3); for italicized values see (4).						
D _w values: Primary source is Table 37 from (1). For underlined values see (3); for italicized values see (4).						
S values: Primary source is Table 36 from (1). For underlined values see (2); for italicized values see (4).						
K _d for mercury from Table 46 in USEPA, 1996a).						
Values for xylenes (total) are for p-xylene.						
Notes:						
(1) USEPA 1996a						
(2) Superfund Chemical Data Matrix (1996)						
(3) CHEMDAT8 (see USEPA, 1994a)						
(4) Calculated using WATER8 (see USEPA, 1994b)						
(5) Hazardous Substances Data Bank						
(6) Calculated from K _{ow} using Eq.70 from USEPA 1996a. K _{ow} from (2), except: benzaldehyde, methyl acetate, MTBE, TBA from (5); caprolactam from (4).						
(7) Calculated from K _{ow} using Eq.71 from USEPA 1996a. K _{ow} from (2), except:methylcyclohexane from (5).						
References:						
Hazardous Substances Data Bank (1999). National Library of Medicine: Bethesda. URL address: http://toxnet.nlm.nih.gov/servlets/simple-search						
Superfund Chemical Data Matrix (1996). United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/R-96/028. URL: http://www.epa.gov/oerpage/superfund/resources/scdm/index.htm						
U.S. Environmental Protection Agency (1994a). CHEMDAT8 User's Guide, November 1994. Office of Air Quality Planning and Standards: Research Triangle Park, NC, EPA-453/C-94-080B.						
U.S. Environmental Protection Agency (1994b). User's Guide for Wastewater Treatment Compound Property Processor and Air Emissions Estimator (WATER8), November 1994. Office of Air Quality Planning and Standards: Research Triangle Park, NJ, EPA-453/C-94-80C.						
U.S. Environmental Protection Agency (USEPA) 1996a. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-95/128.						

Appendix F Sensitivity Analysis - Particulates

Sensitivity Analysis for InhSRS Calculations

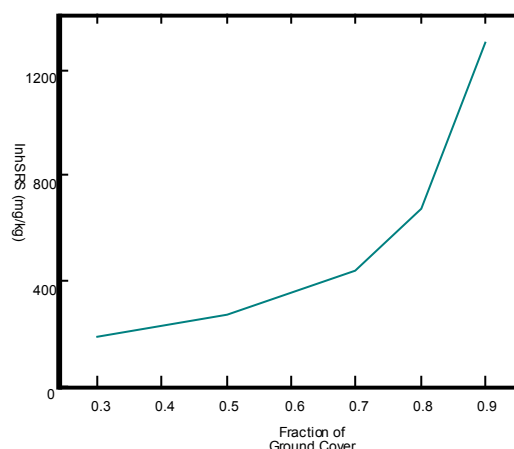
For this sensitivity analysis, only one variable was modified at a time, with the other variables are held at their USEPA default or generic New Jersey value. In most cases, the parameters were varied by documented values. This analysis was conducted for both types of land use: residential and nonresidential. For residential use, the ground cover and wind speed variables in the particulate emission factor taken from USEPA's Soil Screening Guidance: Technical Background Document (1996a) were evaluated. For nonresidential use, variables included in the USEPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites: Peer Review Draft (2001) were evaluated.

Residential

1. Sensitivity of the ground cover to the InhSRS

The amount of vegetative cover assumed for wind erosion effects was 50% as a reasonable compromise between no vegetation and complete cover. The 50% vegetative cover was also assumed as default by USEPA. Vegetative cover has a significant effect.

Ground Cover	InhSRS (mg/kg)
0.3	190
0.5	270
0.7	440
0.8	670
0.9	1,300



2. Sensitivity of mean wind speed to the InhSRS

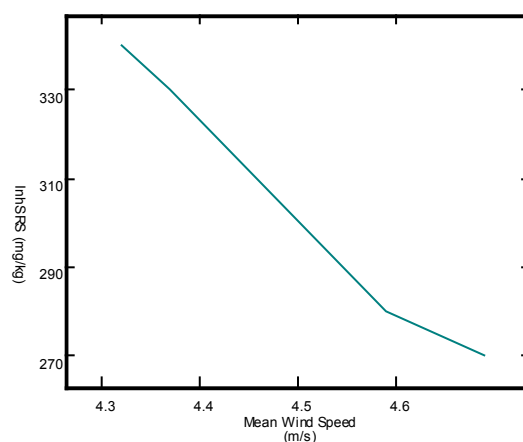
The mean annual wind speed (4.69 m/s) and equivalent threshold wind speed value used in the Department's calculations are default values were taken from USEPA's Soil Screening Guidance: Technical Background Document (1996a). The other mean wind speeds shown are site-specific

values for Philadelphia (4.32 m/s), Atlantic City (4.37 m/s), and Newark (4.59 m/s). These mean wind speeds are 30-year (24-year for Atlantic City) normals statistically calculated by the National Oceanic and Atmospheric Administration (NOAA) (1999a, 1999b, 1999c). The effect of mean wind speed is relatively insignificant. While USEPA's default mean wind speed is slightly more conservative than the site-specific values measured in or near New Jersey, the threshold friction velocity that USEPA assumed is less conservative than the values that would be derived from New Jersey's site-specific mean wind speeds.

Mean
Wind
Speed
(m/s)

InhSRS
(mg/kg)

4.32	340
4.37	330
4.59	280
4.69	270

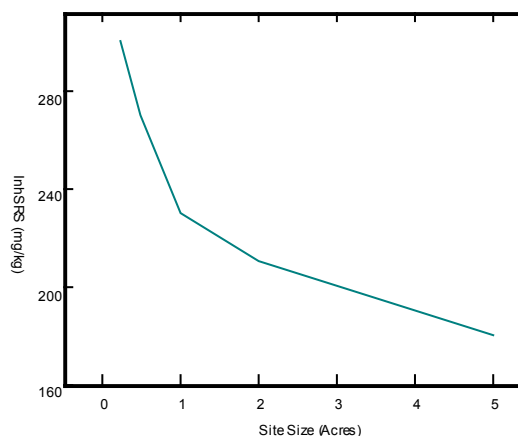


3. Sensitivity of the residential site size to the InhSRS

A large number of comments on USEPA's December 1994 Soil Screening Guidance suggest that the majority of contaminated soil sources are 0.5 acres or less. The USEPA's Office of Emergency and Remedial Response (OERR) conducted an analysis of the effects of changing the default source area from 30 acres to 0.5 acre. The results of the analysis indicated that the InhSRS are sensitive to varying the source area. The reduction in the source area from 30 acres to 0.5 acre **increases** the SSL for the inhalation pathway by about a factor of 2 (USEPA 1996a).

Site Size (Acres)	InhSRS (mg/kg)
-------------------------	-------------------

0.25	300
0.5	270
1	230
2	210
5	180



Nonresidential

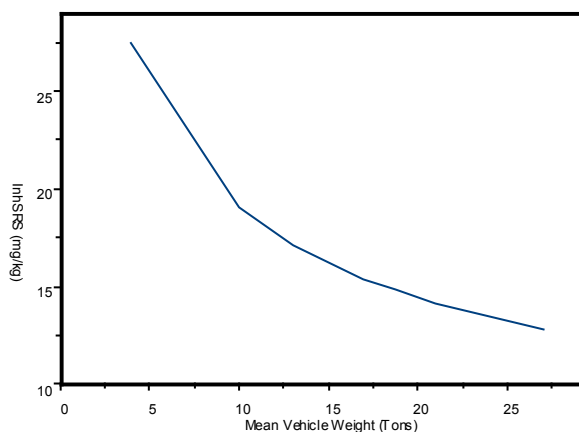
The factors evaluated for sensitivity in regard to the nonresidential scenario are mostly related to vehicle traffic over a site. It is assumed that vehicles can travel anywhere on the site, and that the site is unpaved. Another factor that significantly influences the nonresidential scenario is the amount of time a worker is exposed to dust generated by vehicle travel and other activities at the site.

4. Sensitivity of the mean vehicle weight to InhSRS

Sensitivity of the mean vehicle weight assumed is 18.746 tons, or 17 Metric Tons (Mg). This is a reasonable estimate of the average weight of an eighteen-wheeled tractor-trailer, Scott et al. (1997) estimates that the weight of a tractor-trailer with 18 wheels is approximately 17 Mg. The InhSRS are not particularly sensitive to the average weight of the vehicle.

Mean Veh. Weight (Tons)	InhSRS (mg/kg)
----------------------------------	-------------------

4	27.5
10	19.05
13	17.15
17	15.41
18.75	14.82
21	14.16
27	12.81

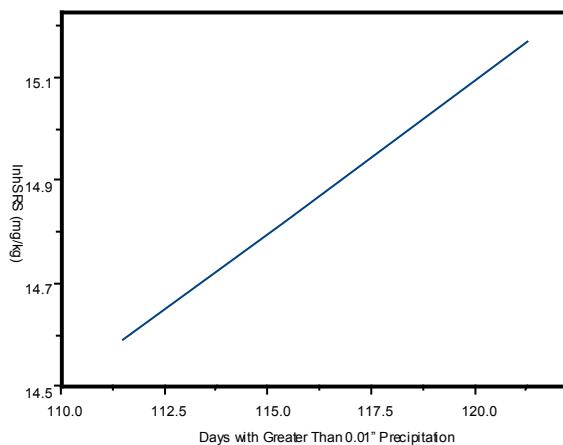


5. Sensitivity of days with greater than 0.01 inches of precipitation to InhSRS

The Department used 115.4 days with 0.01 inch (0.254 mm) of measurable precipitation as its default. This value represents Philadelphia's 30-year average of precipitation days annually. The average number of precipitation days for Atlantic City and Newark are 111.5 and 121.3 days, respectively, over the same 30-year period. The number of precipitation days with 0.01 inch or greater were taken from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data Summaries (1999a, 1999b, 1999c). Adjusting this variable has very little effect on the InhSRS.

Days	InhSRS
w/ >	(mg/kg)
0.01"	
Precip.	

111.5	14.59
115.4	14.82
121.3	15.17



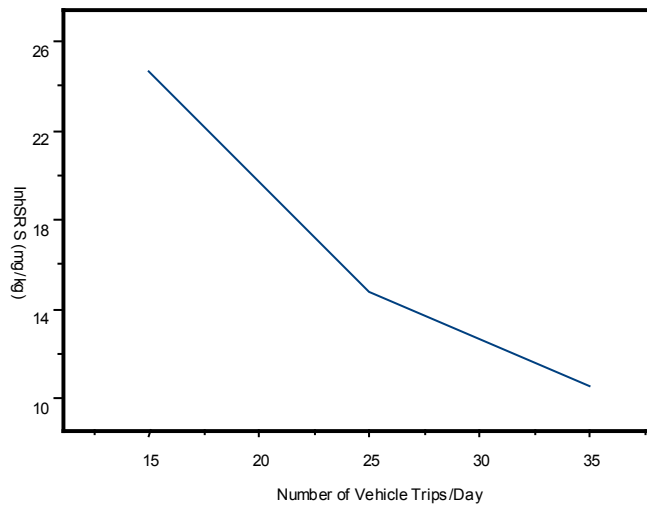
6. Sensitivity of number of vehicle trips per day to the InhSRS

The default vehicle count assumed for a two-acre site is 25 vehicle trips per day. This is a moderate assumption, as this variable can vary significantly by industrial use and site size. For example, Scott et al. (1997) assumed a total of 40 vehicle trips per day for a nonresidential half-acre site. The number of vehicle trips significantly effects the InhSRS.

Number
of Vehicle
Trips/Day

InhSRS
(mg/kg)

15	24.7
25	14.82
35	10.58

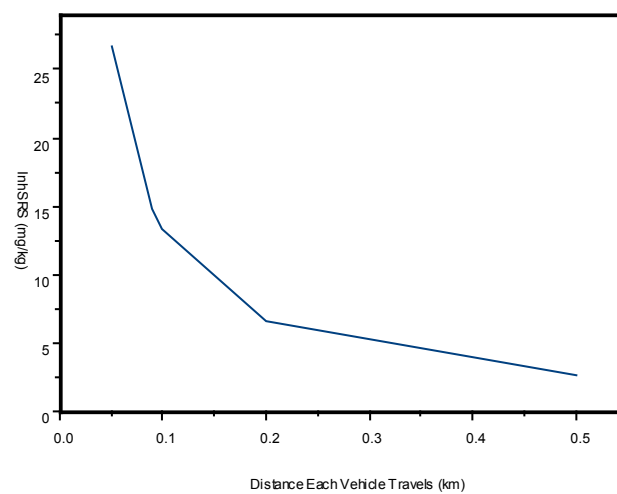


7. Sensitivity of the distance each vehicle travels to InhSRS

The average distance a vehicle travels through an unpaved area is also closely-related to site size. A reasonable estimate as a travel distance is using the square root of the site area in meters. For this sensitivity analysis, however, the site size of two acres was unchanged. See the following sensitivity data for more information on site area and distance traveled.

Distance InhSRS
each Vehicle (mg/kg)
Travels (km)

0.05	26.67
0.09	14.82
0.1	13.34
0.2	6.67
0.5	2.66



8. Sensitivity of size of the nonresidential property to the InhSRS

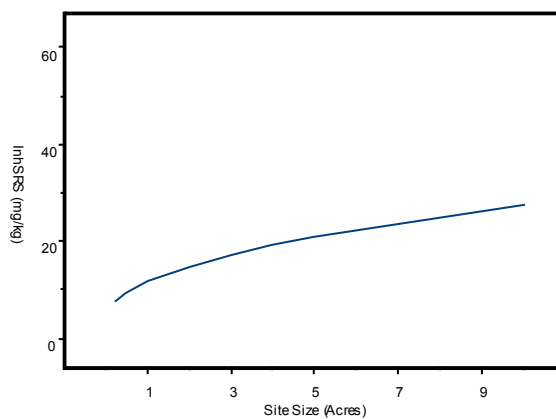
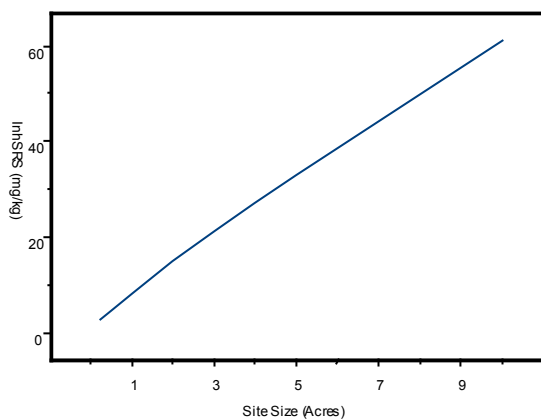
Overall, the InhSRS increases as site size increases. By itself, site size has a significant effect on the InhSRS. When only the site size is changed, the equations assess the same amount of traffic and resuspension of fugitive dust into the air, but diffuse it over the area of the site. Thus, the InhSRS becomes less stringent as the site area is increased. The first set of data show the sensitivity of only changing the site size; the distance traveled remains at 0.09 km for all of the site areas. However, if the distance traveled is adjusted with the site size, the effect of site size is less significant. The second set of data show this correlation.

1) Site InhSRS
 Size (mg/kg)
 (acres)

0.25	2.63
0.5	4.62
1	8.22
2	14.82
3	21.05
4	27.07
5	32.95
10	61.26

2) Site InhSRS
 Size (mg/kg)
 (acres)

0.25	7.46
0.5	9.25
1	11.63
2	14.82
3	17.19
4	19.15
5	20.85
10	27.41

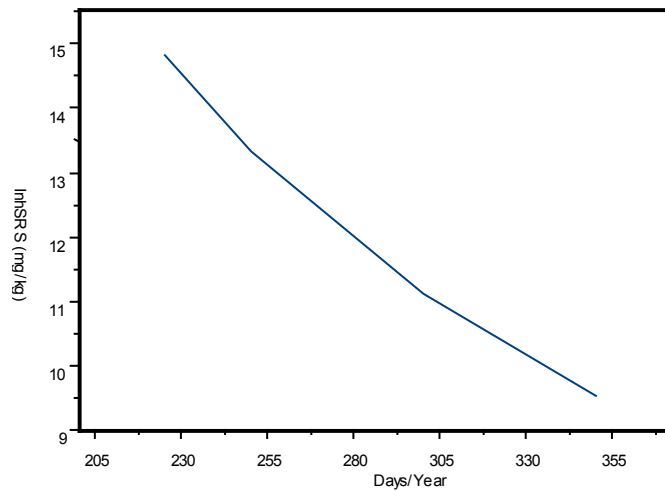


9. Sensitivity of exposure frequency in days per year to the InhSRS

The USEPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Peer Review Draft) recommends an exposure frequency of 225 days per year for the outdoor worker, 250 days per year for an indoor worker, and 350 days per year for residential exposure. Exposure frequency has very little effect on the InhSRS.

Days /Year	InhSRS (mg/kg)
---------------	-------------------

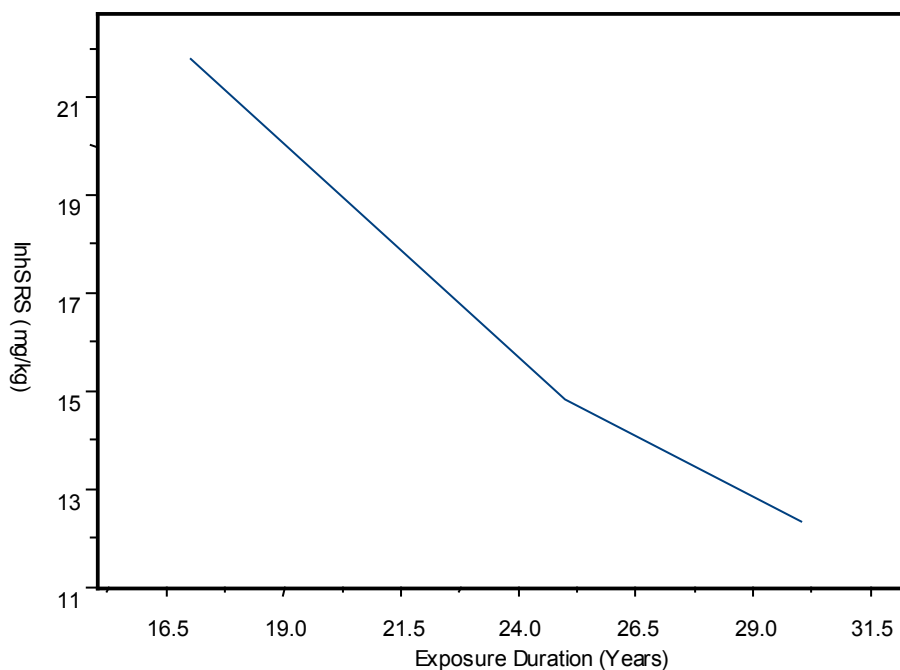
225	14.82
250	13.33
300	11.11
350	9.53



10. Sensitivity of exposure duration in years to the Soil Screening Level (SSL)

The USEPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Peer Review Draft) recommends an exposure duration of 25 years for the nonresidential scenario worker and a duration of 30 years for residential exposure. Exposure duration has a slightly greater effect on the InhSRS than the exposure frequency.

Exposure Duration (Years)	InhSRS (mg/kg)
17	21.79
25	14.82
30	12.35



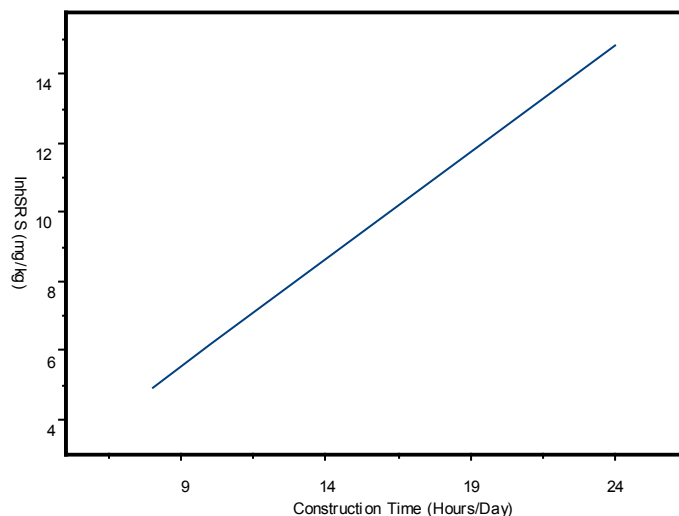
11. Sensitivity of time of construction activity per day to the InhSRS

The Particulate Emission Factor equation proposed in USEPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Peer Review Draft) includes a parameter for the amount of time construction occurs. Since there are already variables accounting exposure frequency and duration in the screening level calculations, it assumed that this parameter represents the amount of time construction occurs during a workday.

This parameter is in the numerator of the PEF equation. Therefore, as the time during which activity occurs is actually **decreased**, the PEF becomes smaller, and, thus, the InhSRS becomes **more stringent**. Based on this information, it would **not** be in a responsible party's best interest discuss to claim that activity occurred less than 24-hours per day. This is a caveat of the proposed USEPA guidance. This parameter significantly effects the InhSRS.

Construction Time (sec)	InhSRS (mg/kg)
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648000	(8 hours/day)	4.94
810000	(10 hours/day)	6.17
1944000	(24 hours/day)	14.82



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Appendix G Site Size Justification

Nonresidential Exposure Scenario:

To calculate an inhalation pathway, soil remediation standard for a nonresidential exposure scenario, it is necessary to determine a default value for the size of a nonresidential site. This information on a statewide basis is not readily available. Two sources of data regarding site size were examined.

One source originates from the Department's program overseeing the remediation of facilities subject to the Industrial Site Recovery Act. Site size information was provided for 154 individual sites. The site sizes ranged from 0.11 acres to 13.16 acres with a median of 1 acre and an upper 95% confidence limit of the median equal to 1.9 acres. The 25th percentile value is 1 acre and the 75th percentile is 3.13 acres. The interquartile range (the range between the 25th and 75th percentile is 2.13 acres. A strict arithmetic mean equals 2.58 acres; however, the population itself appears to be lognormal in nature. Taking this into account, the 95% upper confidence limit of the mean is 3.10 acres. Examination of the inputs yielded a qualitative judgement that this data set would be biased towards small sites since smaller sites would be more numerous in the data set.

The other source originates from the Site Remediation and Waste Management Program conducting remediation using public funds. Specifically, the site data in the Publicly Funded Cleanups Site Status Report for the years 1995 to 2002 was examined. Excluded were landfills, parks, and regional ground water or radiation remediations. Site sizes on 138 sites were obtained. The site sizes range from 0.07 acres to 640 acres with a median of 1.6 acres and an upper 95% confidence limit of the median equal to 2 acres. The 25th percentile value is 0.5 acre and the 75th percentile is 8.8 acres. The interquartile range (the range between the 25th and 75th percentile is 8.3 acres. A strict arithmetic mean equals 16.06 acres; however, the population itself appears to be lognormal in nature. Taking this into account, the 95% upper confidence limit of the mean is 17.86 acres.

It is recognized that the largest sites were excluded from the evaluation in the case of the second set of data. However, as an offset to this, data under the purview of the underground storage tank program were also not included. This type of site, which is extremely numerous, would have a tendency to be smaller in size and consequently would likely reduce the average site size.

The evaluation of above yielded the following conclusion. The available data are lognormal distributions and there is a bias towards the inclusion of smaller sites. The median of these populations provides a better measure of the central tendency than the geometric mean. Because a true mean would necessarily be larger than the median in such a distribution, as well as in consideration of the data bias towards smaller sites, an upper bound of the median could serve as a better measure of central tendency. The upper 95% confidence limits of the two populations are 2 and 3 acres, respectively. The lower 95% confidence limits of the two populations are both 1 acre. It is concluded on this basis that 2 acres represents a reasonable estimate of the average site size of a nonresidential type site.

Residential Exposure Scenario:

In the SSG, the USEPA assumes a residential lot is 0.5 acres in size. Because New Jersey is a small state, but more importantly, because it is the most densely populated state in the United States, an adjustment in lot size was deemed appropriate. Consequently, applying an arbitrary factor of 2, the New Jersey default residential lot size was determined to be 0.25 acres.

Appendix H Table of Inhalation Soil Remediation Standards Based on Contaminant Volatilization

		Residential Standards			Nonresidential Standards	
CHEMICAL		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
Acenaphthene (PAH) *	83-32-9	9.24E+02		6.07E+01	1.55E+03	
Acenaphthylene (PAH) *	208-96-8	6.69E+02		9.07E+01	1.12E+03	
Acetone *	67-64-1		1.58E+06	1.55E+05		2.21E+06
Acetophenone	98-86-2		2.71E+00	1.39E+03		3.80E+00
Acrolein	107-02-8		6.58E-02	3.27E+04		9.22E-02
Acrylonitrile	107-13-1	1.15E+00	6.71E+01	1.17E+04	1.93E+00	9.40E+01
Aldrin	309-00-2	6.38E+00		8.82E+02	1.07E+01	
Anthracene (PAH) *	120-12-7	3.11E+02		2.57E+00	5.22E+02	
Atrazine *	1912-24-9		5.60E+03	6.11E+01		7.84E+03
Benzaldehyde *	100-52-7		3.13E+04	6.34E+02		4.38E+04
Benzene	71-43-2	2.24E+00	2.25E+02	5.22E+02	3.77E+00	3.15E+02
Benzidine	92-87-5	5.78E-03		1.24E+02	9.71E-03	
Benz(a)anthracene (PAH) *	56-55-3	2.22E+02		7.48E+00	3.74E+02	
Benzo(a)pyrene (PAH)*	50-32-8	3.94E+01		3.31E+00	6.62E+01	
Benzo(b)fluoranthene (PAH) *	205-99-2	1.90E+02		3.69E+00	3.20E+02	
Benzo(g,h,i)perylene (PAH) *	191-24-2	1.04E+04		2.01E+00	1.75E+04	
Benzo(k)fluoranthene (PAH) *	207-08-9	5.60E+02		1.97E+00	9.40E+02	

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
1,1-Biphenyl *	92-52-4		6.23E+04	1.04E+02		8.72E+04
Bis(2-chloroethyl)ether	111-44-4	7.15E-01		3.17E+03	1.20E+00	
Bis(2-chloroisopropyl)ether	39638-32-9	3.02E+01		1.14E+03	5.08E+01	
Bis(2-ethylhexyl)phthalate *	117-81-7	1.13E+05	1.16E+06	1.03E+04	1.90E+05	1.63E+06
Bromodichloromethane	75-27-4	1.44E+00		1.83E+03	2.41E+00	
Bromoform	75-25-2	1.27E+02		1.02E+03	2.13E+02	
Bromomethane (Methyl bromide)	74-83-9		3.22E+01	3.12E+03		4.51E+01
2-Butanone (Methyl ethyl ketone) *	78-93-3		5.32E+04	3.42E+04		7.45E+04
Butyl benzyl phthalate *	85-68-7		4.24E+05	3.10E+02		5.94E+05
Caprolactam *	105-60-2		3.06E+05	4.98E+04		4.29E+05
Carbazole *	86-74-8	5.25E+02		5.19E+01	8.82E+02	
Carbon disulfide *	75-15-0		2.38E+03	4.68E+02		3.33E+03
Carbon tetrachloride	56-23-5	7.81E-01	2.01E+02	5.17E+02	1.31E+00	2.81E+02
Chlordane (alpha + gamma) *	57-74-9	1.22E+02	3.65E+03	1.34E+01	2.04E+02	5.11E+03
4-Chloroaniline *	106-47-8		3.00E+03	1.51E+03		4.20E+03
Chlorobenzene *	108-90-7		1.44E+04	2.88E+02		2.02E+04
Chloroethane (Ethyl chloride) *	75-00-3		2.96E+04	1.29E+03		4.14E+04
Chloroform	67-66-3	7.90E-01	2.34E+03	1.98E+03	1.33E+00	3.27E+03

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
Chloromethane (Methyl chloride)	74-87-3	5.40E+00	3.75E+02	1.11E+03	9.07E+00	5.25E+02
4-Chloro-3-methyl phenol ^	59-50-7			9.06E+03		
2-Chlorophenol	95-57-8		1.18E+03	2.05E+04		1.65E+03
Chrysene (PAH) *	218-01-9	1.11E+03		1.27E+00	1.86E+03	
4,4'-DDD (p,p'-TDE)*	72-54-8	7.99E+02		1.80E+02	1.34E+03	
4,4''-DDE (p,p'-DDX)#	72-55-9	8.72E+02		1.07E+03	1.47E+03	
4,4'-DDT *	50-29-3	8.54E+02		1.32E+02	1.44E+03	
Dibenz(a,h)anthracene (PAH) *	53-70-3	9.62E+01		1.89E+01	1.62E+02	
Dibenzofuran ^	132-64-9			2.71E+02		
Dibromochloromethane	124-48-1	3.50E+00		7.37E+02	5.88E+00	
1,2-Dibromo-3-chloropropane	96-12-8	1.05E-01	1.80E+01	3.74E+02	1.76E-01	2.51E+01
1,2-Dibromoethane	106-93-4	3.45E-01	2.60E+01	1.05E+03	5.80E-01	3.64E+01
1,2-Dichlorobenzene (o-) *	95-50-1		6.26E+03	2.18E+02		8.76E+03
1,3-Dichlorobenzene (m-) *	541-73-1		7.85E+03	2.06E+02		1.10E+04
1,4-Dichlorobenzene (p-)	106-46-7	5.88E+00	2.22E+03	1.03E+02	9.87E+00	3.10E+03
3,3'-Dichlorobenzidine #	91-94-1	4.32E+00		4.98E+00	7.26E+00	
Dichlorodifluoromethane *	75-71-8		6.39E+02	5.48E+02		8.95E+02
1,1-Dichloroethane	75-34-3		3.67E+02	1.24E+03		5.14E+02
1,2-Dichloroethane	107-06-2	1.92E+01	5.27E+03	1.64E+03	3.23E+01	7.38E+03

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
1,1-Dichloroethene	75-35-4	3.55E-01	7.92E+02	8.99E+02	5.97E-01	1.11E+03
cis-1,2-Dichloroethene	156-59-2		3.03E+02	8.55E+02		4.24E+02
trans-1,2-Dichloroethene	156-60-5		3.87E+02	1.92E+03		5.41E+02
2,4-Dichlorophenol *	120-83-2		2.90E+03	2.01E+03		4.06E+03
1,2-Dichloropropane	78-87-5	2.41E+00	4.14E+01	7.13E+02	4.05E+00	5.79E+01
1,3-Dichloropropene (cis and trans)	542-75-6	3.06E+00	1.05E+02	9.29E+02	5.15E+00	1.47E+02
Dieldrin	60-57-1	1.50E+00		8.38E+00	2.53E+00	
Diethylphthalate *	84-66-2		1.21E+06	7.88E+02		1.69E+06
2,4-Dimethyl phenol *	105-67-9		2.08E+04	4.50E+03		2.91E+04
Dimethyl phthalate ^	131-11-3			9.09E+02		
Di-n-butyl phthalate *	84-74-2		1.33E+06	7.61E+02		1.86E+06
4,6-Dinitro-2-methylphenol *	534-52-1		1.20E+02	7.71E+01		1.68E+02
2,4-Dinitrophenol *	51-28-5		1.16E+03	4.28E+02		1.63E+03
2,4-Dinitrotoluene	121-14-2	7.31E+00		9.30E+01	1.23E+01	
2,6-Dinitrotoluene	606-20-2	3.09E+00	1.01E+03	5.31E+01	5.19E+00	1.41E+03
Di-n-octyl-phthalate *	117-84-0	2.02E+06		3.33E+03	3.40E+06	
1,2-Diphenylhydrazine	122-66-7	5.98E+00		1.07E+02	1.00E+01	
Endosulfan I & II *	115-29-7		2.18E+04	2.26E+00		3.05E+04
Endosulfan sulfate *	1031-07-8		1.96E+03	1.41E+01		2.74E+03

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
Endrin *	72-20-8		2.53E+03	6.19E+00		3.55E+03
Ethylbenzene *	100-41-4		1.20E+04	1.55E+02		1.67E+04
Fluoranthene (PAH) *	206-44-0	1.03E+04		4.41E+01	1.73E+04	
Fluorene (PAH) *	86-73-7	2.05E+03		5.50E+01	3.44E+03	
a-HCH (a-BHC)	319-84-6	8.53E-01		5.23E+00	1.43E+00	
b-HCH (b-BHC)*	319-85-7	3.39E+00		6.42E-01	5.69E+00	
Heptachlor	76-44-8	2.25E-01		5.09E+02	3.78E-01	
Heptachlor epoxide	1024-57-3	5.87E+00		3.33E+01	9.86E+00	
Hexachlorobenzene	118-74-1	1.91E+00		6.83E+02	3.20E+00	
Hexachloro-1,3-butadiene	87-68-3	1.56E+01		3.48E+02	2.62E+01	
Hexachlorocyclopentadiene	77-47-4		5.82E+01	7.21E+02		8.14E+01
Hexachloroethane	67-72-1	1.08E+02		1.87E+02	1.81E+02	
2-Hexanone	591-78-6			3.63E+03		
Indeno(1,2,3-cd)pyrene (PAH) *	193-39-5	9.16E+02		1.53E-01	1.54E+03	
Isophorone *	78-59-1		3.40E+04	2.96E+03		4.76E+04
Lindane (g-HCH) (g-BHC)	58-89-9	4.45E+00		1.56E+01	7.48E+00	
Mercury	7439-97-6		3.55E+01	---		4.97E+01
Methoxychlor *	72-43-5		1.09E+05	8.80E+00		1.52E+05

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
Methyl acetate *	79-20-9		5.79E+04	3.84E+04		8.11E+04
Methylcyclohexane *	108-87-2		8.85E+03	5.59E+01		1.24E+04
Methylene chloride	75-09-2	4.38E+01	3.53E+03	2.44E+03	7.36E+01	4.94E+03
4-Methyl-2-pentanone (MIBK) *	108-10-1		1.18E+05	3.50E+03		1.65E+05
2-Methylphenol (o-cresol)	95-48-7		1.43E+04	7.66E+04		2.00E+04
4-Methylphenol (p-cresol) *	106-44-5		1.28E+04	6.63E+03		1.79E+04
Methyl tert butyl ether (MTBE)	1634-04-4	1.45E+02	4.86E+03	8.27E+03	2.44E+02	6.80E+03
Naphthalene	91-20-3	2.44E+02	3.45E+01	1.29E+02	4.10E+02	4.83E+01
2-Nitroaniline	88-74-4		5.01E+01	8.74E+01		7.01E+01
Nitrobenzene	98-95-3	2.07E+03	2.13E+02	5.91E+02	3.48E+03	2.98E+02
4-Nitrophenol ^	100-02-7			3.62E+03		
N-Nitrosodimethylamine	62-75-9	2.22E-02		1.54E+05	3.73E-02	
N-Nitrosodi-n-propylamine	621-64-7	2.10E-01		1.99E+03	3.52E-01	
N-Nitrosodiphenylamine*	86-30-6	6.33E+02		9.59E+01	1.06E+03	
PCBs (Polychlorinated biphenyls)	1336-36-3	2.60E+01		4.33E+02	4.37E+01	
Pentachlorophenol	87-86-5	2.76E+02		2.61E+03	4.64E+02	
Phenanthrene (PAH) *	85-01-8	4.32E+03		5.85E+01	7.27E+03	
Phenol *	108-95-2		3.81E+04	1.75E+04		5.34E+04
Pyrene (PAH) *	129-00-0	1.12E+04		2.84E+01	1.88E+04	

CHEMICAL		Residential Standards			Nonresidential Standards	
		Carcinogenic	Noncarcinogenic	Csat	Carcinogenic	Noncarcinogenic
	CAS No.	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg
Styrene	100-42-5	1.16E+02	2.84E+04	5.33E+02	1.95E+02	3.98E+04
Tertiary butyl alcohol (TBA)	75-65-0		5.68E+03	5.74E+04		7.95E+03
1,1,2,2-Tetrachloroethane	79-34-5	1.43E+00		1.01E+03	2.41E+00	
Tetrachloroethene (PCE)	127-18-4	2.45E+00	2.17E+02	1.11E+02	4.12E+00	3.04E+02
Toluene *	108-88-3		3.75E+03	2.89E+02		5.25E+03
Toxaphene	8001-35-2	9.03E+01		3.80E+02	1.52E+02	
1,2,4-Trichlorobenzene *	120-82-1		1.79E+04	1.12E+03		2.50E+04
1,1,1-Trichloroethane *	71-55-6		5.61E+03	6.09E+02		7.85E+03
1,1,2-Trichloroethane	79-00-5	2.66E+00		1.14E+03	4.46E+00	
Trichloroethene (TCE)	79-01-6	9.09E+00	4.67E+03	5.90E+02	1.53E+01	6.54E+03
Trichlorofluoromethane *	75-69-4		3.06E+03	9.44E+02		4.29E+03
2,4,5-Trichlorophenol *	95-95-4		2.71E+05	4.02E+03		3.79E+05
2,4,6-Trichlorophenol	88-06-2	2.84E+02		7.32E+02	4.77E+02	
1,1,2-Trichloro-1,2,2-trifluoroethane *	76-13-1		8.60E+04	5.67E+02		1.20E+05
Vinyl chloride	75-01-4	8.55E-01	3.22E+02	8.94E+02	1.44E+00	4.51E+02
Xylenes (total) *	1330-20-7		1.23E+03	1.79E+02		1.72E+03

Please note that concentrations shaded are critical values for each chemical and exposure scenario within the inhalation pathway.

* Chemical is not regulated because the Csat value for this compound precludes achieving the calculated contaminant concentration in air that would cause an adverse health impact via the inhalation of volatiles.

Chemical is partially not regulated because the Csat value for this compound precludes in part achieving the calculated contaminant concentration in air that would cause an adverse health impact.

^ No toxicity data are available for this chemical as it relates to the inhalation pathway

Standards Based on Particulate Inhalation

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Acenaphthene (PAH)	83-32-9	3.75E+06		5.6E+06		3.18E+05	
Acenaphthylene (PAH)	208-96-8	3.75E+06		5.6E+06		3.18E+05	
Acetone	67-64-1		5.46E+10		6.7E+10		3.86E+09
Acetophenone	98-86-2		3.54E+04		4.4E+04		2.50E+03
Acrolein	107-02-8		3.54E+04		4.4E+04		2.50E+03
Acrylonitrile	107-13-1	6.07E+04	3.54E+06	9.0E+04	4.4E+06	5.14E+03	2.50E+05
Aldrin	309-00-2	8.42E+02		1.2E+03		7.14E+01	
Aluminum	7429-90-5		6.19E+09		7.6E+09		4.37E+08
Anthracene (PAH)	120-12-7	3.75E+05		5.6E+05		3.18E+04	
Antimony	7440-36-0		3.54E+05		4.4E+05		2.50E+04
Arsenic	7440-38-2	9.60E+02	5.31E+04	1.4E+03	6.6E+04	8.13E+01	3.75E+03
Atrazine	1912-24-9		2.12E+07		2.6E+07		1.50E+06
Barium	7440-39-3		8.84E+05		1.1E+06		6.25E+04
Benzaldehyde	100-52-7		6.19E+08		7.6E+08		4.37E+07
Benzene	71-43-2	5.29E+05	5.31E+07		6.6E+07	4.48E+04	3.75E+06

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Benzidine	92-87-5	6.16E+01		9.1E+01		5.22E+00	
Benz(a)anthracene (PAH)	56-55-3	3.75E+04		5.6E+04		3.18E+03	
Benzo(a)pyrene (PAH)	50-32-8	3.75E+03		5.6E+03		3.18E+02	
Benzo(b)fluoranthene (PAH)	205-99-2	3.75E+04		5.6E+04		3.18E+03	
Benzo(g,h,i)perylene (PAH)	191-24-2	3.75E+05		5.6E+05		3.18E+04	
Benzo(k)fluoranthene (PAH)	207-08-9	3.75E+04		5.6E+04		3.18E+03	
Beryllium	7440-41-7	1.72E+03	3.54E+04	2.5E+03	4.4E+04	1.46E+02	2.50E+03
1,1-Biphenyl	92-52-4		3.10E+08		3.8E+08		2.19E+07
Bis(2-chloroethyl)ether	111-44-4	1.25E+04		1.9E+04		1.06E+03	
Bis(2-chloroisopropyl)ether	39638-32-9	4.13E+05		6.1E+05		3.50E+04	
Bis(2-ethylhexyl)phthalate	117-81-7	1.72E+06	1.77E+07	2.5E+06	2.2E+07	1.46E+05	1.25E+06
Bromodichloromethane	75-27-4	1.12E+05		1.7E+05		9.45E+03	
Bromoform	75-25-2	3.75E+06		5.6E+06		3.18E+05	
Bromomethane (Methyl bromide)	74-83-9		8.84E+06		1.1E+07		6.25E+05
2-Butanone (Methyl ethyl ketone)	78-93-3		1.77E+09		2.2E+09		1.25E+08
Butylbenzyl phthalate	85-68-7		1.24E+08		1.5E+08		8.74E+06
Cadmium	7440-43-9	9.83E+02	3.54E+04	1.5E+03	4.4E+04	8.33E+01	2.50E+03

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Caprolactum	105-60-2		3.10E+09		3.8E+09		2.19E+08
Carbazole	86-74-8	7.24E+05		1.1E+06		6.14E+04	
Carbon disulfide	75-15-0		1.24E+09		1.5E+09		8.74E+07
Carbon tetrachloride	56-23-5	2.75E+05	7.07E+07	4.1E+05	8.7E+07	2.33E+04	5.00E+06
Chlordane (alpha + gamma)	57-74-9	4.13E+04	1.24E+06	6.1E+04	1.5E+06	3.50E+03	8.74E+04
4-Chloroaniline	106-47-8		2.48E+07		3.1E+07		1.75E+06
Chlorobenzene	108-90-7		1.77E+09		2.2E+09		1.25E+08
Chloroethane (Ethyl chloride)	75-00-3		1.77E+10		2.2E+10		1.25E+09
Chloroform	67-66-3	1.79E+05	5.31E+08	2.7E+05	6.6E+08	1.52E+04	3.75E+07
Chloromethane (Methyl chloride)	74-87-3	2.29E+06	1.59E+08	3.4E+06	2.0E+08	1.94E+05	1.12E+07
4-Chloro-3-methyl phenol^	59-50-7						
2-Chlorophenol	95-57-8		3.18E+07		3.9E+07		2.25E+06
Chrysene (PAH)	218-01-9	3.75E+05		5.6E+05		3.18E+04	
Cobalt	7440-48-4		8.84E+03		1.1E+04		6.25E+02
Copper	7440-50-8		3.54E+04		4.4E+04		2.50E+03
Cyanide	57-12-5		1.24E+08		1.5E+08		8.74E+06
4,4'-DDD (p,p'-TDE)	72-54-8	5.98E+04		8.9E+04		5.07E+03	

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
4,4'-DDE (p,p'-DDX)	72-55-9	4.25E+04		6.3E+04		3.61E+03	
4,4'-DDT	50-29-3	4.25E+04		6.3E+04		3.61E+03	
Dibenz(a,h)anthracene (PAH)	53-70-3	3.44E+03		5.1E+03		2.91E+02	
Dibenzofuran ^	132-64-9						
Dibromochloromethane	124-48-1	1.53E+05		2.3E+05		1.30E+04	
1,2-Dibromo-3-chloropropane	96-12-8	2.06E+03	3.54E+05	3.1E+03	4.4E+05	1.75E+02	2.50E+04
1,2-Dibromoethane	106-93-4	1.88E+04	1.41E+06	2.8E+04	1.7E+06	1.59E+03	9.99E+04
1,2-Dichlorobenzene (o-)	95-50-1		3.54E+08		4.4E+08		2.50E+07
1,3-Dichlorobenzene (m-)	541-73-1		5.32E+08		6.6E+08		3.76E+07
1,4-Dichlorobenzene (p-)	106-46-7	3.75E+05	1.41E+08	5.6E+05	1.7E+08	3.18E+04	9.99E+06
3,3'-Dichlorobenzidine	91-94-1	1.21E+04		1.8E+04		1.03E+03	
Dichlorodifluoromethane	75-71-8		3.54E+08		4.4E+08		2.50E+07
1,1-Dichloroethane	75-34-3	2.58E+06	8.84E+08	2.4E+05	1.1E+09		6.25E+07
1,2-Dichloroethane	107-06-2	1.59E+05	7.07E+08	2.4E+05	8.7E+08	1.35E+04	5.00E+07
1,1-Dichloroethene	75-35-4		3.54E+07		4.4E+07		2.50E+06
cis-1,2-Dichloroethene	156-59-2		6.19E+07		7.6E+07		4.37E+06
trans-1,2-Dichloroethene	156-60-5		1.06E+08		1.3E+08		7.50E+06

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
2,4-Dichlorophenol	120-83-2		1.95E+07		2.4E+07		1.37E+06
1,2-Dichloropropane	78-87-5	4.13E+05	7.07E+06	6.1E+05	8.7E+06		5.00E+05
1,3-Dichloropropene (cis and trans)	542-75-6	1.03E+06	3.54E+07	1.5E+06	4.4E+07	8.74E+04	2.50E+06
Dieldrin	60-57-1	8.97E+02		1.3E+03		7.60E+01	
Diethylphthalate	84-66-2		4.95E+09		6.1E+09		3.50E+08
2,4-Dimethyl phenol	105-67-9		1.24E+08		1.5E+08		8.74E+06
Dimethyl phthalate ^	131-11-3						
Di-n-butyl phthalate	84-74-2		6.19E+08		7.6E+08		4.37E+07
4,6-Dinitro-2-methylphenol	534-52-1		7.07E+05		8.7E+05		5.00E+04
2,4-Dinitrophenol	51-28-5		1.24E+07		1.5E+07		8.74E+05
2,4-Dinitrotoluene	121-14-2	4.64E+04		6.9E+04		3.93E+03	
2,6-Dinitrotoluene	606-20-2	6.07E+00		9.0E+00		5.14E-01	
Di-n-octylphthalate	117-84-0	3.17E+07		4.7E+07		2.69E+06	
1,2-Diphenylhydrazine	122-66-7	1.88E+04		2.8E+04		1.59E+03	
Endosulfan I & II	115-29-7		3.71E+07		4.6E+07		2.62E+06
Endosulfan sulfate	1031-07-8		3.71E+07		4.6E+07		2.62E+06
Endrin	72-20-8		1.77E+06		2.2E+06		1.25E+05

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Ethylbenzene	100-41-4		1.77E+09		2.2E+09		1.25E+08
Fluoranthene (PAH)	206-44-0	3.75E+06		5.6E+06		3.18E+05	
Fluorene (PAH)	86-73-7	3.75E+06		5.6E+06		3.18E+05	
a-HCH (a-BHC)	319-84-6	2.29E+03		3.4E+03		1.94E+02	
b-HCH (b-BHC)	319-85-7	7.79E+03		1.2E+04		6.60E+02	
Heptachlor	76-44-8	3.17E+03		4.7E+03		2.69E+02	
Heptachlor epoxide	1024-57-3	1.59E+03		2.4E+03		1.35E+02	
Hexachlorobenzene	118-74-1	8.97E+03		1.3E+04		7.60E+02	
Hexachloro-1,3-butadiene	87-68-3	1.88E+05		2.8E+05		1.59E+04	
Hexachlorocyclopentadiene	77-47-4		3.54E+05		4.4E+05		2.50E+04
Hexachloroethane	67-72-1	1.03E+06		1.5E+06		8.74E+04	
2-Hexanone	591-78-6		2.48E+08		3.1E+08		1.75E+07
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	3.75E+04		5.6E+04		3.18E+03	
Isophorone	78-59-1		3.54E+08		4.4E+08		2.50E+07
Lead	7439-92-1	3.44E+05	1.77E+05	5.1E+05	2.2E+05	2.91E+04	1.25E+04
Lindane (g-HCH) (g-BHC)	58-89-9	1.33E+04		2.0E+04		1.13E+03	
Manganese	7439-96-5		8.84E+04		1.1E+05		6.25E+03

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mercury	7439-97-6		5.31E+05		6.6E+05		3.75E+04
Methoxychlor	72-43-5		3.18E+07		3.9E+07		2.25E+06
Methyl acetate	79-20-9		6.19E+09		7.6E+09		4.37E+08
Methylcyclohexane	108-87-2		5.31E+09		6.6E+09		3.75E+08
Methylene chloride	75-09-2	8.78E+06	7.07E+08	1.3E+07	8.7E+08	7.44E+05	5.00E+07
4-Methyl-2-pentanone (MIBK)	108-10-1		5.31E+09		6.6E+09		3.75E+08
2-Methylphenol (o-cresol)	95-48-7		1.06E+08		1.3E+08		7.50E+06
4-Methylphenol (p-cresol)	106-44-5		1.06E+08		1.3E+08		7.50E+06
Methyl tert butyl ether (MTBE)	1634-04-4		5.31E+08		6.6E+08		3.75E+07
Naphthalene	91-20-3	3.75E+06	5.31E+05	5.6E+06	6.6E+05	3.18E+05	3.75E+04
Nickel	7440-02-0		3.54E+05		4.4E+05		2.50E+04
2-Nitroaniline	88-74-4		3.54E+05		4.4E+05		2.50E+04
Nitrobenzene	98-95-3		3.54E+06		4.4E+06		2.50E+05
4-Nitrophenol ^	100-02-7						
N-Nitrosodimethylamine	62-75-9	2.95E+02		4.4E+02		2.50E+01	
N-Nitrosodi-n-propylamine	621-64-7	2.06E+03		3.1E+03		1.75E+02	
N-Nitrosodiphenylamine	86-30-6	1.59E+06		2.4E+06		1.35E+05	

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PCBs (Polychlorinated biphenyls)	1336-36-3	4.13E+04		6.1E+04		3.50E+03	
Pentachlorophenol	87-86-5	8.09E+05		1.2E+06		6.86E+04	
Phenanthrene (PAH)	85-01-8	3.75E+06		5.6E+06		3.18E+05	
Phenol	108-95-2		3.54E+08		4.4E+08		2.50E+07
Pyrene (PAH)	129-00-0	3.75E+06		5.6E+06		3.18E+05	
Selenium	7782-49-2		3.54E+07		4.4E+07		2.50E+06
Silver	7440-22-4		3.18E+07		3.9E+07		2.25E+06
Styrene	100-42-5	7.24E+06	1.77E+09		2.2E+09	6.14E+05	1.25E+08
Tertiary butyl alcohol (TBA)	75-65-0		1.11E+08		1.4E+08		7.87E+06
1,1,2,2-Tetrachloroethane	79-34-5	7.12E+04		1.1E+05		6.03E+03	
Tetrachloroethene (PCE)	127-18-4	6.99E+05	6.19E+07	1.0E+06	7.6E+07	5.93E+04	4.37E+06
Thallium	7440-28-0		3.71E+05		4.6E+05		2.62E+04
Toluene	108-88-3		7.07E+08		8.7E+08		5.00E+07
Toxaphene	8001-35-2	1.29E+04		1.9E+04		1.09E+03	
1,2,4-Trichlorobenzene	120-82-1		3.54E+08		4.4E+08		2.50E+07
1,1,1-Trichloroethane	71-55-6		1.77E+09		2.2E+09		1.25E+08
1,1,2-Trichloroethane	79-00-5	2.50E+05		3.7E+05		2.12E+04	

CHEMICAL	CAS No.	Residential Standards		Nonresidential Standards for Sites Less Than 2 Acres		Nonresidential Standards for Sites 2 or More Acres	
		Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Trichloroethene (TCE)	79-01-6	2.06E+06	1.06E+09	3.1E+06	1.3E+09	1.75E+05	7.50E+07
Trichlorofluoromethane	75-69-4		1.24E+09		1.5E+09		8.74E+07
2,4,5-Trichlorophenol	95-95-4		6.19E+08		7.6E+08		4.37E+07
2,4,6-Trichlorophenol	88-06-2	1.33E+06		2.0E+06		1.13E+05	
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1		5.31E+10		6.6E+10		3.75E+09
Vanadium	7440-62-2		4.42E+07		5.5E+07		3.12E+06
Vinyl chloride	75-01-4	4.69E+05	1.77E+08	7.0E+05	2.2E+08	3.97E+04	1.25E+07
Xylenes	1330-20-7		1.77E+08		2.2E+08		1.25E+07
Zinc	7440-66-6		1.59E+06		2.0E+06		1.12E+05

Please note that concentrations highlighted are critical values for each chemical and exposure scenario within the inhalation pathway.

^ No toxicity data are available for this chemical as it relates to the inhalation pathway.

Appendix I Calculation of an Alternative Remediation Standard using the EMSOFT Model and a Finite Contamination Thickness

Introduction

The generic remediation guidance uses a simplified form of the model of Jury et al. (1990), which assumes an infinite depth of contamination. The full version of this model allows for a finite depth range to be specified (Jury et al., 1990). Assuming a finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a higher remediation standard. Calculation of an Alternative Remediation Standard using the Jury model is likely to be worthwhile (result in a higher criteria) if the thickness of the contaminated zone is not extensive. To calculate this site-specific standard, the EMSOFT software package is recommended. The package is available on the Internet from USEPA's National Center for Environmental Assessment (<http://www.epa.gov/nceawww1/emsoft.htm>). Software documentation (in PDF format) may also be downloaded from the site.

Theoretical basis

For volatile organic chemicals (dimensionless Henry's law constant $\gg 2.5 \times 10^{-5}$), volatilization from the soil surface is limited only by the diffusion rate through the soil, with no restriction imposed by the stagnant air layer at the soil surface (Jury et al., 1984). If soil moisture advection is not considered, and if a chemical is assumed to be present from the soil surface to an infinite depth, the volatilization flux equation can be expressed as follows (Jury et al., 1984):

$$J = C_0 (D_A / \pi \times t)^{1/2}, \quad (1)$$

where J is the volatilization flux ($\text{mg}/\text{cm}^2/\text{day}$) as a function of time t (days), C_0 is the concentration of contaminant at time zero on a volume basis (mg/cm^3), and D_A is the soil

diffusion coefficient (cm²/day, from Equation 6 of the EPA SSG document). An average volatilization flux may be calculated by integrating Equation 1 from time 0 to time t, to give cumulative flux, and dividing by the time interval:

$$\frac{\int_0^t C_0 (D_A / \pi \times t)^{1/2}}{t} \quad (2)$$

The solution to this equation is

$$2C_0 \sqrt{D_A / \pi \times t}. \quad (3)$$

If Equation 3 is normalized for concentration by dividing C_0 (which has units of mg/cm³) by the initial concentration on a weight basis (C_s , which has units of mg/g), the equation is transformed to

$$2\rho_b\sqrt{D_A/\pi\times t}, \quad (4)$$

where Equation 4 now represents the average volatilization flux per unit concentration of contaminant on a weight basis, and ρ_b is the bulk density of the soil as described in the EPA SSG document (g/cm^3). Note that Equation 4 is equivalent to the inverse of the second factor of Equation 6 in the EPA SSG document. Thus, the average volatilization flux using the Jury model can be used along with the inverse of the mean concentration at the center of a square source ($\text{g/m}^2/\text{s}$ per kg/m^3 – see Q/C factor of Equation 6 in the EPA SSG document) to calculate the volatilization factor.

While the above derivation was carried out using a simplified form of the Jury model, the average volatilization flux from the full Jury model can be used in the same manner. The full version of the Jury model (Jury et al., 1990) considers a finite source of contaminant located in a depth range of L to $L + W$, where L is the depth of the top of the contamination, and W is the thickness of the contamination. Advection of soil moisture, due to precipitation infiltration, may also be considered, as well as degradation of the contaminant. These additional features in the full version of the model may result in a significantly lower average volatilization flux, and in turn, a higher calculated remediation standard. The full version of the Jury model may be evaluated using the EMSOFT program, available without charge on the Internet (USEPA, 1997).

Calculation of Alternative Remediation Standard using EMSOFT

Calculating an alternative inhalation soil remediation standard for volatile organic chemicals requires three steps:

1. Calculation of the time-averaged volatilization flux of contaminant from the soil using the model of Jury et al.
2. Calculation of the Volatilization Factor (VF) from the time-averaged volatilization flux.
3. Calculation of the soil remediation criteria using the exposure assumptions assumed during calculation of the generic remediation standards.

Step 1: Running the Jury model (using the EMSOFT software package) to obtain the time-averaged volatilization flux.

Several types of output are available from the program. For purposes of the NJDEP remediation criteria, the time-averaged flux output is all that is necessary. The program should be run for the exposure period of interest (30 years, or 10,958 days). Chemical degradation is not allowed for these calculations. A 1 mg/kg concentration of contaminant must be used, in order to correctly calculate the volatilization factor.

1. Begin execution of the EMSOFT program by double-clicking on EMSOFT.BAT
2. A title screen comes up. Click on the OK button.
3. If you have previously saved a chemical input file (*.CHM) or a complete input scenario (*.DAT) file that you wish to use, click on the appropriate selection box and the desired file name, and then click on OK. If you will be entering new data, simply click on OK.
4. Select the time-averaged flux box by clicking on it. Then click on the Time period for averaging.... box and enter 10,958 days. For depths D1 and D2, first click on the data entry box, then enter the depth to groundwater, in cm. Then click on OK. If depth to groundwater is not known, enter a depth below the location of the contamination.

5. Enter the chemical data by clicking on each selection box and entering the appropriate values (see following table). If you wish to save this chemical data in a file for future use, click on the selection box, click on the name entry box (leave the .CHM part alone), and enter the name. Then click on OK.

<u>Parameter</u>	<u>Value</u>
Organic carbon partition coefficient (mL/g, or L/kg)	Chemical specific ^a
Henry's law constant (dimensionless)	Chemical specific ^a
Air diffusion coefficient (cm ² /day)	Chemical specific ^{a,b}
Aqueous diffusion coefficient (cm ² /day)	Chemical specific ^{a,b}
Half-life (days)	1000000 ^c
Number of contaminant layers	1 ^c

^a Use values from Appendix E.

^b Multiply the DEP values (cm²/s) by 86,400 s/day to obtain units of cm²/day.

^c This parameter value may not be changed.

6. Enter the soil properties and physical constants, using the following table as guidance, then click on OK:

<u>Parameter</u>	<u>Value</u>
Fraction organic carbon	0.002 ^d
Porosity (v/v, dimensionless)	0.41 ^e
Water content (v/v, dimensionless)	0.23 ^e
Bulk density (g/cm ³)	1.5 ^e
Porewater flux (cm/day)	0.08 ^f
Boundary layer thickness (cm)	0.5 ^e

^d This may be adjusted using site-specific measurements (see text).

^e This parameter value may not be changed.

^f This parameter value may not be changed without consultation with the Department.

Corresponds to New Jersey annual infiltration rate (see Appendix D).

7. Enter layer properties using the following table, then click on OK:

<u>Parameter</u>	<u>Value</u>
Cover thickness (cm)	Site-specific ^g
Layer thickness (cm)	Site-specific ^h
Contaminant concentration (mg/kg)	1 ⁱ

^g Enter the shallowest depth at which contamination is observed (cm). If contamination extends to the soil surface, enter 0.

^h Enter the thickness, in cm, of the contaminated soil. This is the lowest depth at which contamination is observed minus the shallowest depth at which contamination is observed.

ⁱ This value may not be changed.

8. If you wish to save the entire input scenario and/or the output data in a file, check the appropriate box, click on the name entry box, and enter the desired name (leave the .DAT and .OUT part of the name intact. Then click on OK.

9. The program then calculates the time-averaged flux (average surface flux). Write down the value shown. Then click on OK.

Step 2: Calculate the Volatilization Factor (VF)

1. Convert the time-averaged volatilization flux (mg/cm²/day) to units of gm/m²/sec. To do this, multiply by 10,000 cm²/m², divide by 86,400 sec/day, and divide by 1000 mg/g.
2. Divide the converted value by 10⁻⁶ to give the normalized volume-based flux, J (gm/m²/sec).
3. Calculate the VF as follows:

$$VF = \frac{Q / C}{J}$$

where Q/C is 117 (g/m²/sec)/(kg/m³), and VF is the volatilization factor (m³/kg).

Step 3: Calculate the site-specific soil remediation criteria using the above VF value

Use Equation 1 or 2 from the main guidance for this exposure pathway.

References

- Jury, W.A., Farmer, W.J. and Spencer, W.F. (1984). Behavior Assessment Model for Trace Organics in Soil: II Chemical Classification and Parameter Sensitivity. *J. Environ. Qual.*, 13(4):567-572.
- Jury, W.A., Russo, D., Streile, G., and Abd, H.E. (1990). Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface. *Water Resour. Res.*, 26(1):13-20.

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Office of Research and Development, National Center for Environmental Assessment,
NCEA-W-0073.

Appendix J Compliance Protocol

1. Is the site a residential or nonresidential exposure scenario? Go to 2 if residential or 16 if not.
2. If residential, is the site less than 0.25 acres in size or not? Go to 3 if less than 0.25 acres in size or 9 if not.
3. If less than 0.25 acres in size, divide the residential site into 2 meter thick layers starting at the ground surface. Go to 4.
4. Determine appropriate generic remediation standard for the contaminants of concern using for each contaminant the lowest residential generic soil remediation standard for the inhalation pathway (Table 7 of this document). Go to 5.
5. Determine if alternative remediation standards apply. If so use them in the subsequent steps. Go to 6.
6. Compare generic/alternative remediation standards for the inhalation pathway against the other pathways. If the inhalation pathway standard is lower than the appropriate standard for all the other pathways go to 7. Otherwise, use the compliance mechanism for the pathway with the lowest relevant standard. The inhalation pathway is not the critical pathway at this time.
7. For each 2 meter thick layer, starting with the most contaminated calculate the 95% upper confidence level of the mean of the values in that layer if the sample results are deemed by the Department to be representative of the contamination present. If not, it may be necessary to divide each layer into clean and contaminated zones and then calculate the resultant area/volume prorated 95% upper confidence level of the mean for that layer. Do any of the calculated 95% upper confidence limit of the means for the layers exceed

the relevant inhalation pathway standards? If so remedial action is required to address inhalation pathway concerns. For either alternative, go to 8.

8. Do any of the values in a layer fail compliance in the other pathways? If single point exceedance is the compliance mechanism, it is possible to pass the 95% upper confidence limit of the mean of the inhalation pathway, but fail the single point compliance mechanism of another pathway. If the appropriate inhalation pathway standard is not exceeded and if the other pathways are not issues, there is no regulatory concern relative to the pathways evaluated. If a pathway other than inhalation is an issue, then the need for remedial action is determined using the procedures for that pathway.
9. If the residential site is equal to or greater than 0.25 acres, divide the site into 0.25 acre blocks. The shape of the blocks ideally are rectangular in shape, but are allowed to vary to accommodate the site-specific situation. The placement and shape of these areas will be dictated by the contaminant distribution on site and are to be biased toward the evaluation of the worst case situation. For remnant areas that are less than 0.125 acres, the associated sample results may be incorporated into the calculations of adjacent 0.25 acre blocks. If the remnant areas are equal to or more than 0.125 acres, but less than 0.25 acres, these blocks may be evaluated as if they were full 0.25 acre blocks. Go to 10.
10. Divide the blocks into 2 meter thick layers relative to ground surface. Go to 11.
11. Determine appropriate generic remediation standard for the contaminants of concern using for each contaminant the lowest residential generic soil remediation standard for the inhalation pathway (Table 7 of this document). Go to 12.
12. Determine if alternative remediation standards apply. If so use them in the subsequent steps. Go to 13
13. Compare generic/alternative remediation standards for the inhalation pathway against the other pathways. If the inhalation pathway standard is lower than the appropriate standard

for all the other pathways go to 14. Otherwise, use the compliance mechanism for the pathway with the lowest relevant standard. The inhalation pathway is not the critical pathway at this time.

14. For each 2 meter thick layer, starting with the most contaminated calculate the 95% upper confidence level of the mean of the values in that layer if the sample results are deemed by the Department to be representative of the contamination present. If not, it may be necessary to divide each layer into clean and contaminated zones and then calculate the resultant area/volume prorated 95% upper confidence level of the mean for the layer. Do any of the calculated 95 % upper confidence limit of the means for the layers exceed the inhalation pathway standard in the critical values table or a relevant alternative remediation standard? If so remedial action is required to address inhalation pathway concerns. For either alternative, go to 15.
15. Do any of the values in a layer fail compliance in the other pathways? If single point exceedance is a pathway's compliance mechanism, it is possible to pass the 95% upper confidence limit of the mean of the inhalation pathway, but fail the single point compliance mechanism of another pathway. If the appropriate inhalation pathway standard is not exceeded and if the other pathways are not issues, there is no regulatory concern relative to the pathways evaluated. If a pathway other than inhalation is an issue, then the need for remedial action is determined using the procedures for that pathway.
16. If the site is nonresidential, is the site less than 2 acres in size? If so go to 17. If not, go to 24.
17. If the nonresidential site is less than 2 acres, the Department has determined that vehicle traffic impacts do not need to be addressed. Evaluation of airborne particulates will consider only wind borne dust generation. Go to 18.
18. Divide the site into 2 meter thick layers starting at the ground surface. Go to 19.

19. Determine appropriate generic remediation standard for the contaminants of concern using the appropriate nonresidential values found in the Lowest Generic Soil Remediation Standards for the Inhalation Pathway Table (Table 7 of this document). Go to 20.
20. Determine if alternative remediation standards apply. If so use them in the subsequent steps. Go to 21.
21. Compare generic/alternative remediation standards for the inhalation pathway against the other pathways. If the inhalation pathway standard is lower than the appropriate standard for all the other pathways go to 22. Otherwise, use the compliance mechanism for the pathway with the lowest relevant standard. The inhalation pathway is not the critical pathway at this time.
22. For each 2 meter thick layer, starting with the most contaminated calculate the 95% upper confidence level of the mean of the values in that layer if the sample results are deemed by the Department to be representative of the contamination present. If not, it may be necessary to divide each layer into clean and contaminated zones and then calculate the resultant area/volume prorated 95% upper confidence level of the mean for the layer. Do any of the calculated 95% upper confidence limits for the layers exceed the relevant inhalation pathway standard? If so remedial action is required to address inhalation pathway concerns. Go to 23.
23. Do any of the values in a layer fail compliance in the other pathways? If single point exceedance is a pathway's compliance mechanism, it is possible to pass the 95% upper confidence limit of the mean for the inhalation pathway, but fail the single point compliance mechanism of another pathway. If the appropriate inhalation pathway standard is not exceeded and if the other pathways are not issues, there is no regulatory concern relative to the pathways evaluated. If a pathway other than inhalation is an issue, then the need for remedial action is determined using the procedures for that pathway.

24. If the nonresidential site is equal to or greater than 2 acres, divide the site into 2 acre blocks. The shape of the blocks ideally are rectangular in shape, but are allowed to vary to accommodate the site-specific situation. The placement and shape of these areas will be dictated by the contaminant distribution on site and are to be biased toward the evaluation of the worst case situation. For remnant areas that are less than 1 acre, the associated sample results may be incorporated into the calculations of adjacent 2 acre blocks. If the remnant areas are equal to or more than 1 acre, but less than 2 acres, these blocks may be evaluated as if they were full 2 acre blocks. Go to 25.
25. Divide the blocks into 2 meter thick layers relative to ground surface. Go to 26.
26. Determine appropriate generic remediation standard for the contaminants of concern using the appropriate nonresidential values found in the Lowest Generic Soil Remediation Standards for the Inhalation Pathway Table (Table 7 of this document). Go to 27.
27. Determine if alternative remediation standards apply. If so use them in the subsequent steps. Go to 28
28. Compare generic/alternative remediation standards for the inhalation pathway against the other pathways. If the inhalation pathway standard is lower than the appropriate standard for all the other pathways go to 29. Otherwise, use the compliance mechanism for the pathway with the lowest relevant standard. The inhalation pathway is not the critical pathway at this time.
29. For each 2 meter thick layer, starting with the most contaminated calculate the 95% upper confidence level of the mean of the values in that layer if the sample results are deemed by the Department to be representative of the contamination present. If not, it may be necessary to divide each layer into clean and contaminated zones and then calculate the resultant area/volume prorated 95% upper confidence level of the mean for the layer. Do any of the calculated 95% upper confidence limits for the layers exceed the inhalation

pathway standard found in the critical value table or a relevant alternative remediation standard? If so remedial action is required to address inhalation pathway concerns. For either alternative, go to 30.

30. Do any of the values in a layer fail compliance in the other pathways? If single point exceedance is a pathway's compliance mechanism, it is possible to pass the 95% upper confidence limit of the mean of the inhalation pathway, but fail the single point compliance mechanism. If the appropriate inhalation pathway standard is not exceeded and if the other pathways are not issues, there is no regulatory concern relative to the pathways evaluated. If a pathway other than inhalation is an issue, then the need for remedial action is determined using the procedures for that pathway.